Aug. 9, 1966 J. R. HARNISH 3,264,839

HEAT PUMPS FOR SIMULTANEOUS COOLING AND HEATING

Filed May 12, 1964 3 Sheets-Sheet 1

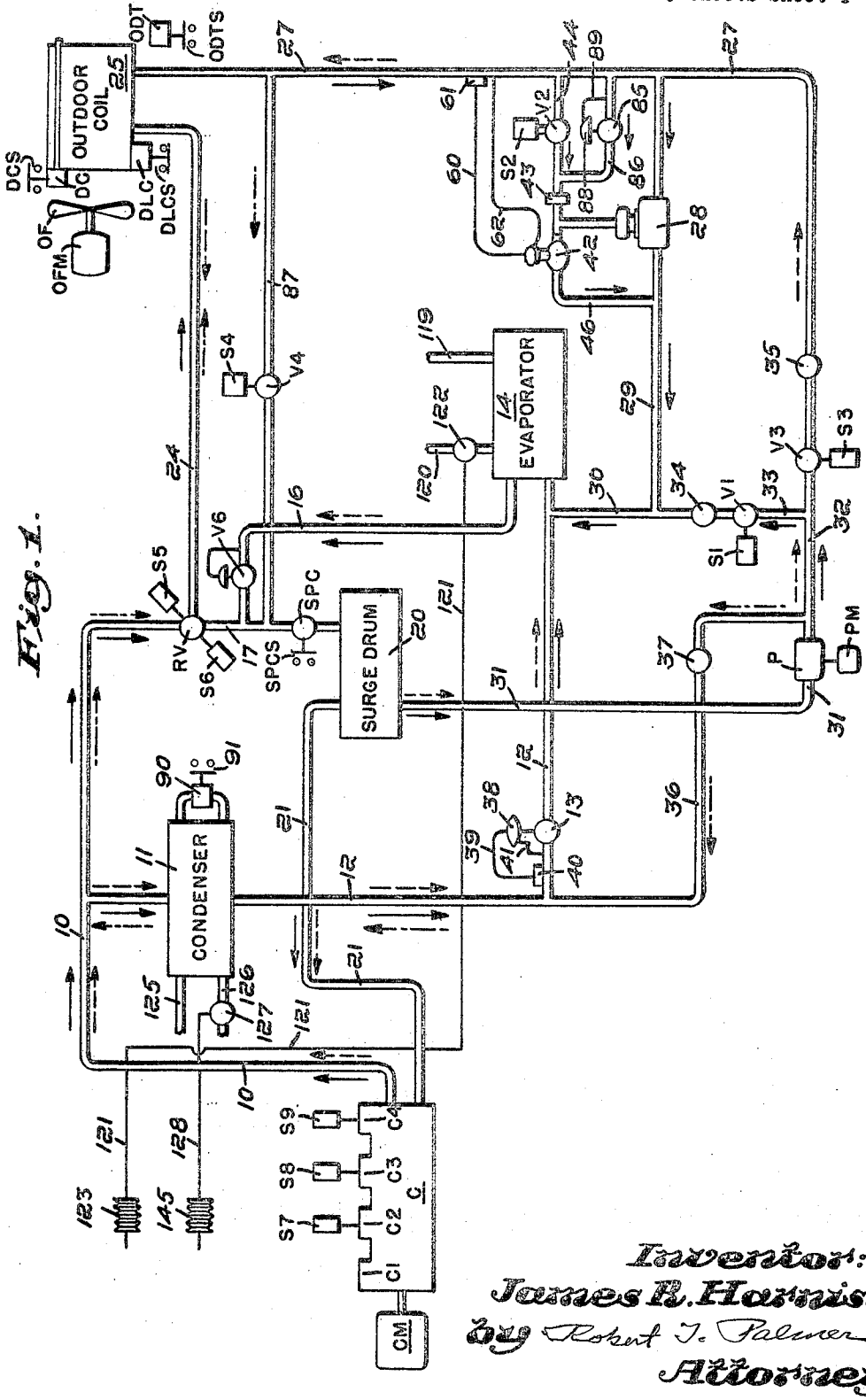


Fig. 1.

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Attorney

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HEAT PUMPS FOR SIMULTANEOUS COOLING AND HEATING

Filed May 12, 1964 3 Sheets-Sheet 2

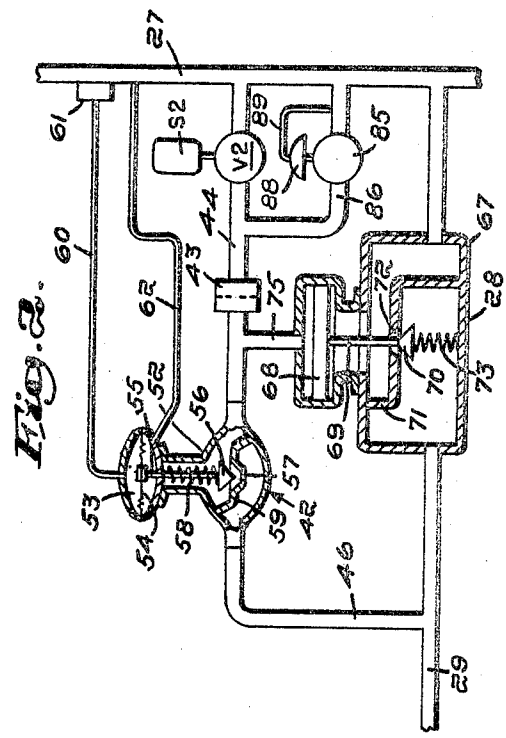


Fig. 2.

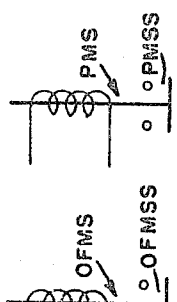


Fig. 5a.

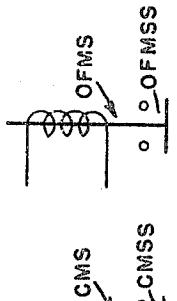


Fig. 5b.

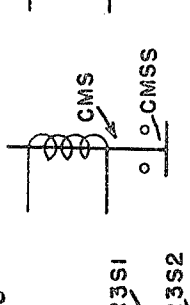


Fig. 5c.

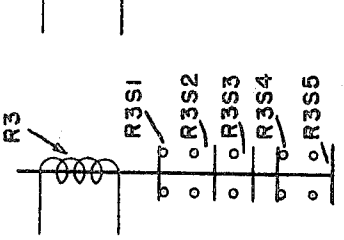


Fig. 5d.

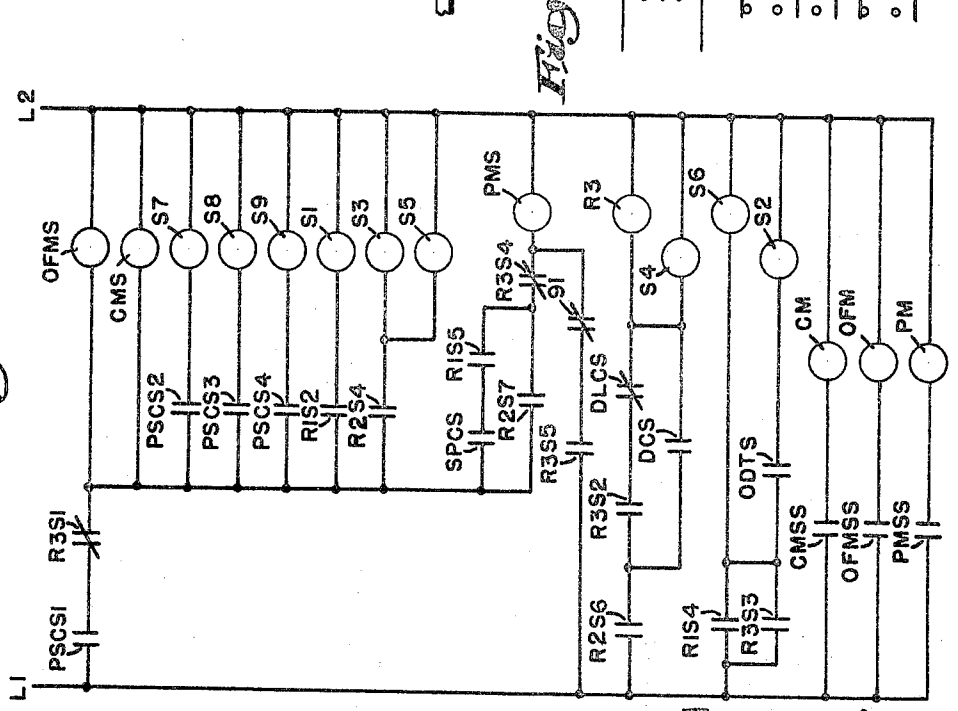


Fig. 1.

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HEAT PUMPS FOR SIMULTANEOUS COOLING AND HEATING

Filed May 12, 1964 3 Sheets-Sheet 3

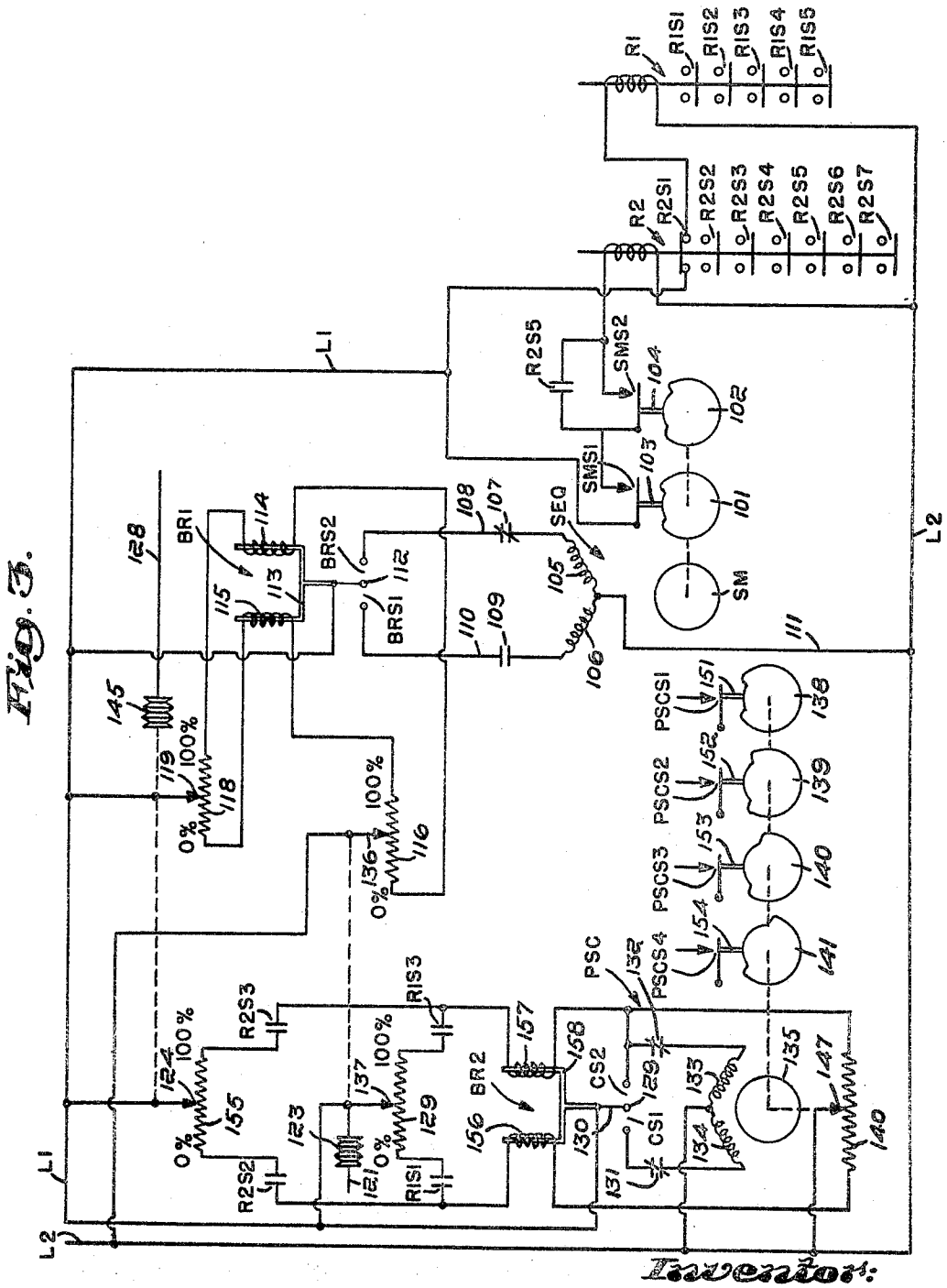


Fig. 3.

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United States Patent Office 3,264,839 Patented August 9, 1966

3,264,839

HEAT PUMPS FOR SIMULTANEOUS COOLING AND HEATING

James R. Harnish, Staunton, Va., assignor to Westinghouse Electric Corporation, Pittsburgh, Pa., a corporation of Pennsylvania

Filed May 12, 1964, Ser. No. 367,287
31 Claims. (Cl. 62—160)

This invention relates to heat pumps that are used to cool indoor air in parts of buildings, and to simultaneously heat indoor air in other parts of the buildings.

A heat pump used for cooling and heating indoor air simultaneously in different parts of a building, has an indoor heat exchanger that operates as a condenser, and has another indoor heat exchanger that operates as an evaporator. My U.S. Patent No. 3,109,298 discloses such a heat pump which, when the cooling load is greater than the heating load, operates an outdoor air heat exchanger as an additional condenser, and when the heating load is greater than the cooling load, operates the outdoor air heat exchanger as an additional evaporator. In such a heat pump, the refrigerant flow through the outdoor air heat exchanger is always in the same direction, requiring that both lines of the outdoor air heat exchanger serve as liquid and vapor lines which have to be relatively large, and require a relatively large charge of refrigerant. Unevaporated refrigerant is stored in a surge drum, and a liquid pump operates continuously during both cycles, to pump liquid from the surge drum to the heat exchangers that are operating as evaporators.

This invention is an improvement over that of my patent in that reversal valve means is used to reverse the flow of refrigerant, between cycles, through the outdoor air heat exchanger so that one line of the latter always serves as a liquid line, and its other line always serves as a vapor line. The liquid line, therefore, can be smaller and require less insulation than either line of the outdoor air heat exchanger of my patent, and a smaller refrigerant charge can be used. Another advantage of the present invention over that of my patent is that its liquid pump need not operate continuously when the cooling load is greater than the heating load.

Another feature of this invention is that controls are provided which determine when the cooling load or the heating load is greater, and which automatically use the outdoor heat exchanger as a condenser when the cooling load is greater, and which automatically use the outdoor heat exchanger as an evaporator when the heating load is greater.

An object of this invention is to improve heat pumps that are used to cool indoor air in portions of buildings and simultaneously heat indoor air in other portions of the buildings.

Another object of this invention is to reduce the costs of heat pumps that are used to cool indoor air in portions of buildings and simultaneously heat indoor air in other portions of the buildings.

Another object of this invention is to defrost the outdoor heat exchanger of a heat pump used for simultaneously cooling and heating indoor air.

Another object of this invention is to provide means for determining automatically when the cooling load of a heat pump is greater than its heating load, and vice versa, and which control the operation of the heat pump.

FIG. 1 is a diagrammatic view of a heat pump embodying this invention;

FIG. 2 is an enlarged view, in section, of the main expansion valve and of its pilot valve, and of their connections;

FIG. 3 is a circuit schematic of a portion of the control circuit of the heat pump;

FIG. 4 is a simplified circuit schematic of the other portion of the control circuit;

FIG. 5*a* is a diagrammatic view of the defrost relay;

FIG. 5*b* is a diagrammatic view of the compressor motor starter;

FIG. 5*c* is a diagrammatic view of the fan motor starter, and

FIG. 5*d* is a diagrammatic view of the pump motor starter.

On FIG. 1, the solid line arrows indicate the refrigerant flow when the cooling load is the greater; the dashed line arrows indicate the refrigerant flow when the heating load is greater, and the dash-dot line arrows indicate the refrigerant flow during defrosting of the outdoor coil.

A refrigerant compressor C driven by an electric motor CM, is connected by discharge line **10** to the refrigerant inlet of a shell-and-tube condenser **11**, the refrigerant outlet of which is connected by liquid line **12** and expansion valve **13** to the refrigerant inlet of shell-and-tube evaporator **14**. The refrigerant outlet of the evaporator **14** is connected through line **16** and pressure regulating valve V6 into line **17** which connects refrigerant reversal valve RV to surge drum **20**. The line **17** contains a control SPC responsive to pressure therein, and which has a switch SPCS which closes when the pressure is reduced to a predetermined minimum. The valve V6 maintains an evaporator temperature above 32° F. for preventing freezing of the water that the evaporator **14** chills. The drum **20** is connected by line **21** to the suction side of the compressor C. The discharge line **10** is also connected to the reversal valve RV, and through the latter and line **24** to outdoor coil **25** when the cooling load is greater than the heating load as will be described later. An outdoor air fan OF driven by an electric motor OFM, moves outdoor air over the coil **25** when the motor OFM is energized. Liquid from the outdoor coil **25** when it is operating as a condenser, flows through line **27**, main expansion valve **28** and lines **29–30** into the refrigerant inlet of the evaporator **14**.

The surge drum **20** is connected by liquid line **31** to the inlet of liquid pump P which is driven by an electric motor PM. The outlet of the pump P is connected through lines **32** and **33**, valve V1 controlled by solenoid S1, check valve **34** and the line **30** to the refrigerant inlet of the evaporator **14**. The outlet of the pump P is also connected through the line **32**, valve V3 controlled by solenoid S3, and check valve **35** to the line **27** for supplying liquid to the outdoor coil **25** when it is operating as an evaporator as will be described later. The line **12** from the condenser **11** is connected through line **36** and check valve **37** to the outlet of the pump P.

The expansion valve **13** has a diaphragm chamber **38**, the upper portion of which, above a diaphragm, which is not shown, is connected by a small tube **39** to thermal bulb **40** in contact with the line **12**, and the lower portion of which, below the diaphragm, is connected by equalizer tube **41** to the interior of the line **12**. The valve **13** responds to the temperature and pressure of the liquid in the line **12**, and maintains a predetermined amount of subcooling which may be 10° F., at a condensing temperature of 100° F., as disclosed in my copending application, Serial No. 309,861, filed Sept. 18, 1963.

The main expansion valve **28** is controlled by a conventional expansion valve **42** acting as a pilot valve, as shown by FIG. 2. The inlet of the valve **42** is connected through an orifice **43**, line **44** and valve V2 controlled by a solenoid S2, to the line **27**. The outlet of the valve **42** is connected by line **46** to the line **29**. The valve **42** has a casing **52** around a diaphragm chamber **53**. A diaphragm **54** extends across the center of the chamber **53**, and is connected at its center to the upper end of rod

55 of valve piston 56. The piston 56 is above a valve opening 57 in a partition 59 extending between the inlet and outlet of the valve 42. A coiled spring 58 extends between the bottom of the chamber 53 and the top of the piston 56, and biases the piston 56 towards closed position. The chamber 53 above the diaphragm 54 is connected by a small tube 60 to a thermal bulb 61 in contact with the line 27. The chamber 53 below the diaphragm 54 is connected by an equalizing tube 62 to the interior of the line 27. Liquid from the line 27 when the outdoor coil 25 is operating as a condenser, flows through the valve V2 and the orifice 43 into the valve 42. The main expansion valve 28 has a casing 67 containing a piston 68 connected at its center to the upper end of a piston rod 69 which has a valve piston 70 on its lower end. A partition 71 extends between the inlet and outlet of the valve 28, and has a valve opening 72 therein above the piston 70. The top of the valve 28 above the piston 68 is connected by line 75 to the inlet of the valve 42. A coiled spring 73 extends between the bottom of the piston 70 and the bottom of the casing 67, and biases the piston 70 towards closed position.

In the operation of the valves 28 and 42, a decrease in the amount of subcooling of the liquid in the line 27 when it is operating as a liquid line, below, for example, 10° F., at a condensing temperature of 100° F., causes the pressure above the diaphragm 54 to increase and thereby causes the diaphragm 54 to move the piston 56 towards its closed position. This bleeds pressure from above the top of the piston 68 of the valve 28 to downstream of the latter, permitting the spring 73 to move the piston 70 towards closed position so as to back up more liquid for more subcooling. A valve 85 is connected in a line 86 across the valve V2. The valve 85 has a diaphragm chamber 88 connected by a small tube 89 to the interior of the line 86.

The lines 27 and 17 are connected by a line 87 containing a valve V4 adjusted by a solenoid S4. A float control 90 responds to refrigerant liquid level in the condenser 11, and has a switch 91 which closes when such level is low.

The evaporator 14 has a chilled water outlet connection 119 and a return water connection 120 for use with local air cooling coils which are not shown. The connection 120 preferably contains a proportioning thermostat 122 connected by a small tube 121 to a bellows 123 although this thermostat could be in the connection 119. The condenser 11 has a heated water outlet connection 126 and a return water connection 126 for use with local air heating coils which are not shown. Preferably the connection 126 contains a proportional thermostat 127 connected by a small tube 128 to a bellows 145, although the thermostat 127 could be in the connection 125.

The reversal valve RV is adjusted by a solenoid S5 when the latter is energized, to operate the outdoor coil 25 as an evaporator, and is adjusted by a solenoid S6 when the latter is energized, to operate the coil 25 as a condenser. The solenoid S5 is deenergized when the solenoid S6 is energized, and vice versa, as will be explained later.

The compressor motor CM, the fan motor OFM and the pump motor PM have starters CMS, OFMS and PMS respectively.

A defrost control DC responds to air pressure drop across the coil 25 caused by the formation of a substantial amount of frost thereon when the coil 25 is operating as an evaporator at low outdoor temperatures, and has a normally open switch DCS which closes when the coil 25 needs to be defrosted. A defrost limit control DLC responds to refrigerant pressure within the coil 25, and has a normally closed switch DLCS which opens when the pressure within the coil 25 rises as a result of the frost having melted from it.

As shown by FIG. 3, a conventional sequencer SEQ has cam discs 101 and 102 rotated by an electric motor SM. The motor SM has a forward field winding 105, and a reverse field winding 106. The winding 105 is connected at one end through limit switch 107 and wire 108 to switch BRS2 of a conventional balancing relay BR1. The winding 106 is connected at one end through limit switch 109 and wire 110 to switch BRS1 of the relay BR1. The other ends of the windings 105 and 106 are connected by wire 111 to electric supply line L2. The relay BR1 has an armature 112 connected to electric supply line L1, and which is moved by a pivoted, U-shaped core 113 having a winding 114 on one leg, and a winding 115 on its other leg. Corresponding ends of the windings 114 and 115 are connected to the ends of potentiometer 116. The other ends of the windings 114 and 115 are connected to the ends of potentiometer 118. Slider 119 of the potentiometer 118 is electrically connected to the electric line L1, and is mechanically connected to the bellows 145. The latter is also connected to slider 124 of potentiometer 155, which slider is electrically connected to the electric line L1. The ends of the potentiometer 125 are connected through switches R2S2 and R2S3 of relay R2 to corresponding ends of windings 156 and 157 on the legs of pivoted, U-shaped core 158 of conventional balancing relay BR2 of conventional, proportioning type, step controller PSC, and through switches R1S1 and R1S3 of relay R1 to the ends of potentiometer 129. Armature 130 of the core 158 is connected to the electric line L1, and is movable to close switch CS1 or CS2 which are connected through limit switches 131 and 132 respectively, to corresponding ends of forward field winding 133 and reverse field winding 134 of motor 135. The other ends of the windings 133 and 134 are connected to the electric line L2. Sliders 136 and 137 of the potentiometers 116 and 129 respectively, are electrically connected to the electric lines L2 and L1 respectively, and are connected mechanically to the bellows 123. The other ends of the windings 156 and 157 are connected to the ends of potentiometer 140, slider 147 of which is movable by the motor 135. The motor 135 also rotates cam discs 138, 139, 140 and 141 which have cam followers 151, 152, 153 and 154 respectively. The cam follower 151 closes switch PSCS1 when the motor 135 starts to rotate in a counterclockwise direction with respect to FIG. 3, at the start of a cycle, and maintains the switch PSCS1 closed until the end of the cycle. The cam followers 152, 153 and 154 successively close switches PSCS2, PSCS3 and PSCS4 respectively, during continued rotation of the motor 135 in the counterclockwise direction, and successively open such switches when the motor 135 rotates in the opposite direction. As shown by FIG. 4, the switches PSCS2, PSCS3 and PSCS4 are electrically connected to solenoids S7, S8 and S9 respectively. Such switches when closed energize such solenoids which operate the conventional loaders-unloaders of cylinders C2, C3 and C4 of the compressor C, which loaders-unloaders are not shown. Cylinder C1 of the compressor C has no such loader-unloader. The solenoids S7, S8 and S9, when energized, load their respective cylinders C2, C3 and C4, and when deenergized, unload their respective cylinders.

The heating control thermostat 127 and the cooling control thermostat 122 adjust the potentiometers 155 and 129 respectively, in the usual manner to accomplish control of the compressor motor, and the compressor cylinder loading and unloading. This invention adds a second potentiometer 118 to the thermostat 127, a second potentiometer 116 to the thermostat 122, the sequencer SEQ, and the relays R1 and R2, and uses the switches R1S2 and R1S3 of the cooling control relay R1 to place the cooling control thermostat 122 in control of the cylinder loading and unloading when the cooling load is greater than the heating load, and uses the switches R2S2 and R2S3 of the heating control relay R2 to place the heating control thermostat 127 in control of the cylinder loading and unloading when the heating load is greater than the cooling load.

Referring now to FIG. 4, the switch PSCS1 is con-

nected in series with switch R3S1 of defrost relay R3, and the fan motor starter OFMS to the electric lines L1. The compressor motor starter CMS is connected in parallel with OFMS. The solenoid S7 is connected in series with switches PSCS2, R3S1 of the relay R3 and PSCS1 to the electric lines. The solenoid S8 is connected in series with the switches PSCS3, R3S1 of the relay R3 and PSCS1 to the electric lines. The solenoid S9 is connected in series with the switches PSCS4, R3S1 of the relay R3 and PSCS1 to the electric lines. The solenoid S1 is connected in series with the switches R1S1 of the relay R1, R3S1 of the relay R3 and PSCS1 to the electric lines. The solenoid S3 is connected in series with the switches R2S4 of the relay R2, R3S1 of the relay R3 and PSCS1 to the electric lines. The solenoid S5 is connected in parallel with the solenoid S3. The pump motor starter PMS is connected in one path in series with the switches R3S4 of the relay R3, R1S5 of the relay R1, SPCS of the control SPC, R3S1 of the relay R3 and PSCS1 to the electric lines, and in another path is connected in series with the switches 91 of the float control 90 and R3S5 of the relay R3 to the electric lines. Switch R2S7 of the relay R2 is connected across the series connection of the switches SPCS and R1S5. The defrost relay R3 is connected in series with the switches DLCS of the defrost limit control DLC, R3S2 of the relay R3 and R2S6 of the relay R2 to the electric lines. The solenoid S4 is connected in parallel with the relay R3. The switch DCS of the defrost control DC is connected in parallel with the series connection of the switches R3S2 and DLCS. The solenoid S6 is connected in series with the switch R1S4 of the relay R1 to the electric lines. Switch R3S3 of the relay R3 is connected in parallel with the switch R1S4. The solenoid S2 is connected in series with the switch ODTS of the outdoor thermostat ODT across the solenoid S6. Switch CMSS of the compressor motor starter CMS is connected in series with the compressor motor CM to the electric lines. Switch OFMSS of the fan motor starter OFMS in connected in series with the fan motor OFM to the electric lines. Switch PMSS of the pump motor starter PMS is connected in series with the pump motor PM to the electric lines.

Operation

When the heating load becomes greater than the cooling load, the heating control thermostat 127 moves through the bellows 145, the slider 119 of the potentiometer 118 nearer its 100% point than the cooling control thermostat 122 moves through the bellows 123, the slider 136 of the potentiometer 116. This causes more current to flow through the winding 114 of the relay BR1 than flows through its winding 115, causing the armature 112 to close the switch BRS2, supplying current to the field winding 105 of the sequencer motor SM, causing the latter to rotate in a clockwise direction with respect to FIG. 3, and to rotate the cam discs 101 and 102 in the same direction. The cam follower 103 closes the switch SMS1, and shortly thereafter, the cam follower 104 closes the switch SMS2, connecting the heating control relay R2 to the electric lines. The now energized relay R2 opens its switch R2S1 disconnecting the cooling control relay R1 from the electric lines, and closes its switches R2S2, R2S3, R2S4, R2S5, R2S6 and R2S7. The switch R2S5 is a holding circuit switch connected across the switch SMS2 for maintaining the relay R2 energized for a short period after the motor SM reverses as will be described later, and the switch SMS2 opens. By operating the switches SMS1 and SMS2 in sequence, a time delay is provided so that the system will not continuously cycle back and forth when the heating and cooling loads are nearly in balance. The now closed switches R2S2 and R2S3 connect the potentiometer 125 to the balancing relay BR2, causing the motor 135 to be energized and to rotate in a direction to load or unload cylinders of the compressor C as required by its heating load. The closed

switch R2S4 energizes through the closed switch R3S1 of the relay R3, the solenoid S5 which adjusts the reversal valve RV to the position for operating the outdoor coil 25 as an evaporator, and energizes the solenoid S3 which opens the valve V3 to connect the pump P to the outdoor coil 25. The closed switch R2S7 is connected across the switches SPCS and R1S5, and closes the energizing circuit of the pump motor starter PMS, starting the pump. The closed switch R2S6 connects the defrost initiating switch DCS through the defrost relay R3, to the electric line L1 for permitting defrosting of the coil 25 when necessary, as will be described later.

Discharge gas from the compressor C flows through the line 10 into the condenser 11. Liquid refrigerant from the condenser 11 flows through the expansion valve 13 into the evaporator 14. Gas and any unevaporated liquid from the evaporator 14 flows through the line 16, the pressure regulating valve V6 and the line 17 into the surge drum 20, the gas separated from the liquid within the surge drum flowing through the suction gas line 21 to the compressor C. The pump P supplies liquid from the surge drum into the outdoor coil 25 which is now operating as an evaporator. The valve V1 is closed at this time through its solenoid S1 being deenergized by the open switch R1S1 of the now deenergized relay R1. Gas and any unevaporated liquid from the coil 25 flows through the line 24 and the reversal valve RV into the surge drum 20, being mixed therein with refrigerant from the evaporator 14.

When the cooling load becomes greater than the heating load, the cooling control thermostat 122 moves through the bellows 123, the slider 136 of the potentiometer 116 nearer its 100% point than the heating control thermostat moves the slider 119 of the potentiometer 118. This causes more current to flow through the winding 115 of the relay BR1 than flows through its winding 114, causing its armature 112 to close the switch BRS1, supplying current to the field winding 106 of the sequencer motor SM, causing the latter to rotate the cam discs 101 and 102 in a counterclockwise direction so that the cam follower 104 opens the switch SMS2, and shortly thereafter the cam follower 103 opens the switch SMS1 for deenergizing the heating control relay R2. The holding circuit switch R2S5 of the relay R2, connected across the switch SMS2, maintains the relay R2 energized until the switch SMS1 opens, providing time delay during the change-over for permitting the system operation to stabilize, and to avoid hunting between cycles.

The deenergized relay R2 closes its switch R2S1, connecting the cooling control relay R1 to the electric lines, and opens its switches R2S2, R2S3, R2S4, R2S5, R2S6 and R2S7 which deenergize the previously described circuits in which they are connected. The now energized relay R1 closes its switches R1S1, R1S2, R1S3, R1S4 and R1S5. The closed switch R1S1 energizes the solenoid S1 which opens the valve V1 permitting the pump P to pump liquid refrigerant from the surge drum 20 into the evaporator 14. The valves V3 and V4 are closed at this time since their solenoids S3 and S4 respectively, are deenergized through the now open switches R2S4 and R2S6 respectively. The now closed switches R1S2 and R1S3 connect the potentiometer 129 to the windings 156 and 157 of the relay BR2, causing the motor 135 to rotate in a direction to load or unload cylinders of the compressor C as required by the cooling load under control of the thermostat 122. The now closed switch R1S4 of the relay R1 energizes the solenoid S6 to adjust the reversal valve RV to route discharge gas from the line 10, through the line 24 into the outdoor coil 25 to operate the later as a condenser. The now closed switch R1S5 of the relay R1 permits energization of the pump motor starter PMS when the switch SPCS of the valve SPC closes.

The compressor C supplies discharge gas through the line 10 into the condenser 11 and the reversal valve RV, flowing from the latter through the line 24 into the out-

door coil 25 operating as a condenser. Liquid refrigerant from the condenser 11 flows through the line 12 and expansion valve 13 into the evaporator 14. Liquid refrigerant from the outdoor coil 25 flows through the line 27, expansion valve 28 and line 29 into the evaporator 14. Liquid refrigerant from the surge drum 20 flows through the line 31 into the pump P, and from the latter when it is operating, through the valve V1 and line 30 into the evaporator 14. The pump motor starter PMS is energized to start the pump motor PM by the pressure control SPC in the line 16 when the pressure within the latter falls to a predetermined value, so as to prevent the evaporator 14 from starving, the switch SPCS being closed at such time, and energizing the starter PMS through the switch R1S5 of the relay R1.

Gas and any unevaporated liquid from the evaporator 14 flows through the line 16 and the valve V6 into the surge drum 20. Gas separated from the liquid within the surge drum flows through the suction gas line 21 to the compressor C.

When the outdoor temperature is low, the increased condensing capacity of the outdoor coil 25 may greatly lower the condensing temperature, preventing the condenser 11 from receiving sufficient heat to satisfy the heating load. To prevent this, the pressure regulating valve 85 is provided in the line connecting the pilot valve 42 to the line 27, and is preset to maintain a sufficiently high pressure to prevent the expansion valve 28 from opening until sufficient liquid has backed up within the outdoor coil 25 to reduce its condensing capacity. The valve V2 is connected across the valve 85, and its solenoid S2 is energized by the closing of the switch ODTS of the outdoor thermostat ODT, to open the valve V2 when the outdoor temperature is high enough to reduce the heating load. This permits the coil 25 to operate at lower condensing temperatures, improving the system efficiency.

At low outdoor temperatures when the outdoor coil 25 is operating as an evaporator, frost may form on the coil 25. When sufficient frost has formed on the coil 25 to affect its performance, the increased air pressure drop across the coil 25 causes the switch DCS of the defrost control DC to close and energize the defrost relay R3, and the solenoid S4. The energized solenoid S4 opens the valve V4. The energized relay R3 closes its switches R3S2, R3S3 and R3S4 and opens its switches R3S1 and R3S4. The open switches R3S1 and R3S4 open the energizing circuits of the motor starters CMS and OFMS, the solenoids S7, S8, S9, S1 and S5, and that portion of the energizing circuit of the pump motor starter PMS which includes the switches SPCS, R1S5 and R2S7. The compressor and fan motors are turned off. The pump motor starter PMS can only be energized through the switches 91 of the float control 90, and R3S5 of the relay R3. The closed switch R3S2 is a holding circuit switch connected across the switch DCS for maintaining the defrost relay R3 energized when the switch DCS opens as a result of the stopping of the fan motor OFM, and the cessation of air flow through the coil 25. The closed switch R3S3 energizes the solenoid S6 which adjusts the reversal valve RV to supply gas from the condenser 11 which is now operating as an evaporator, through the line 24 into the coil 25 to operate the latter as a condenser for melting the frost thereon. Liquid from the coil 25 flows through the line 87 and the now open valve V4, and the pressure control SPC into the surge drum 20. The closed switch R3S5 establishes a circuit to the float switch 91, permitting the latter to energize the pump motor starter PMS to operate the pump P intermittently as the refrigerant liquid level in the condenser 11 falls and rises. Liquid from the surge drum 20 is pumped by the pump P, when the latter operates, through the check valve 37 and the lines 36 and 12 into the condenser 11 operating as an evaporator. The pump P is controlled by the float switch 91 to keep some of the condenser tubes immersed in liquid refrigerant. The valves V1 and V3 are closed at this time as a result of their solenoids S1 and S3 respectively, being deenergized by the now open switches R3S1 and R3S4 of the defrost relay R3.

When the frost has melted from the coil 25, the increased refrigerant pressure within the latter causes the switch DLCS of the defrost limit control DLC to open, deenergizing the defrost relay R3 and the solenoid S4. The solenoid S4 closes the valve V4. The deenergized relay R3 opens its switches R3S2, R3S3 and R3S5, and closes its switches R3S1 and R3S4, returning the system back to normal operation with the outdoor air coil 25 operating as an evaporator as it was when the frost formed on it.

In the annexed claims, "heat sink exchanger" is defined as "a heat exchanger exposed to a heat absorbing or heat dissipating source."

I claim:

1. A heat pump for cooling indoor air in a portion of a building and simultaneously heating indoor air in another portion of the building, comprising a refrigerant compressor; a condenser for heating fluid for supply to local air heating units, and having its refrigerant inlet connected to the discharge side of said compressor; an evaporator for chilling fluid for supply to local air cooling units, and having its refrigerant inlet connected to the refrigerant outlet of said condenser; a surge drum having a gas outlet connected to the suction side of said compressor, and having a gas and unevaporated liquid inlet connected to the refrigerant outlet of said evaporator; a pump having an inlet connected to receive liquid refrigerant from said drum, and having an outlet connected to said inlet of said evaporator; a heat sink exchanger, and having one side connected to said inlet of said evaporator and to said outlet of said pump; reversal valve means connected to said discharge side of said compressor, to the other side of said heat exchanger, and to said inlet of said drum; means when the cooling load is greater than the heating load for adjusting said valve means to route gas from said discharge side of said compressor to said other side of said heat exchanger, and for routing liquid from said pump to said inlet of said evaporator; and means when the heating load is greater than the cooling load for routing liquid from said pump to said one side of said heat exchanger, and for adjusting said valve means to route gas and unevaporated liquid from said other side of said heat exchanger to said inlet of said drum.

2. A heat pump as claimed in claim 1 in which control means is provided for sensing when the cooling load is greater than the heating load, and for sensing when the heating load is greater than the cooling load, and in which means is provided for operating with said control means said means for adjusting said valve means to route discharge gas from said discharge side of said compressor to said other side of said heat exchanger, and said means for routing liquid from said pump to said inlet of said evaporator, when the cooling load is greater than the heating load, and in which means is provided for operating with said control means said means for routing liquid from said pump to said one side of said heat exchanger, and said means for adjusting said valve means to route gas and unevaporated liquid from said other side of said heat exchanger to said inlet of said drum, when the heating load is greater than the cooling load.

3. A heat pump as claimed in claim 2 in which said pump has driving means, and in which means including means responsive to the pressure of the refrigerant in the connection of said outlet of said evaporator to said inlet of said drum is provided for energizing said driving means.

4. A heat pump as claimed in claim 3 in which the connection of said one side of said heat exchanger to said inlet of said evaporator includes expansion means

responsive to the temperature and pressure of the refrigerant at said one side of said heat exchanger.

5. A heat pump as claimed in claim 4 in which said connection of said one side of said heat exchanger to said inlet of said evaporator includes means for preventing said expansion means from opening below a preset condensing pressure in said heat heat exchanger when said valve means is adjusted to route discharge gas from said compressor to said heat exchanger, and in which means including means responsive to outdoor air temperature is provided for disabling said means for preventing said expansion means from opening.

6. A heat pump as claimed in claim 1 in which control means is provided for sensing when the cooling load is greater than the heating load, and for sensing when the heating load is greater than the cooling load, in which means is provided for operating with said control means said means for adjusting said valve means to route discharge gas from said discharge side of said compressor to said other side of said heat exchanger, and said means for routing liquid from said pump to said inlet of said evaporator, when the cooling load is greater than the heating load, in which means is provided for operating with said control means said means for routing liquid from said pump to said one side of said heat exchanger, and said means for adjusting said valve means to route gas and unevaporated liquid from said other side of said heat exchanger to said inlet of said drum, when the heating load is greater than the cooling load, and in which the connection of said one side of said heat exchanger to said inlet of said evaporator includes expansion valve means responsive to the temperature and pressure of the refrigerant at said one side of said heat exchanger.

7. A heat pump as claimed in claim 6 in which means is provided for preventing said expansion valve means from opening below a preset condensing pressure in said heat exchanger when said reversal valve means is adjusted to route discharge gas from said compressor to said heat exchanger, and in which means including means responsive to outdoor temperature is provided for disabling said means for preventing said expansion valve means from opening.

8. A heat pump as claimed in claim 1 in which said pump has driving means, and in which means including means responsive to the pressure of the refrigerant in the connection of said outlet of said evaporator to said inlet of said drum is provided for energizing said driving means.

9. A heat pump as claimed in claim 8 in which the connection of said one side of said heat exchanger to said inlet of said evaporator includes expansion valve means responsive to the temperature and pressure of the refrigerant at said one side of said evaporator.

10. A heat pump as claimed in claim 9 in which means is provided for preventing said expansion valve means from opening below a preset condensing pressure in said heat exchanger when said reversal valve means is adjusted to route discharge gas from said compressor to said heat exchanger, and in which means including means responsive to outdoor temperature is provided for disabling said means for preventing said expansion valve means from opening.

11. A heat pump as claimed in claim 1 in which the connection of said one side of said heat exchanger to said inlet of said evaporator includes expansion valve means responsive to the temperature and pressure of the refrigerant at said one side of said heat exchanger.

12. A heat pump as claimed in claim 11 in which means is provided for preventing said expansion valve means from opening below a preset condensing temperature in said heat exchanger when said reversal valve means is adjusted to route discharge gas from said compressor to said heat exchanger, and in which means including means responsive to outdoor temperature is provided for disabling said means for preventing said expansion valve means from opening.

13. A heat pump for cooling indoor air in a portion of a building and simultaneously heating indoor air in another portion of the building, comprising a refrigerant compressor; a condenser for heating fluid for supply to local air heating units, said condenser having a fluid outlet connection and a fluid return connection, and having its refrigerant inlet connected to the discharge side of said compressor; an evaporator for chilling fluid for supply to local air cooling units, said evaporator having a fluid outlet connection and a fluid return connection, and having its refrigerant inlet connected to the refrigerant outlet of said condenser; reversal valve means; a heat sink exchanger, said heat exchanger having one side connected to said refrigerant inlet of said evaporator; means connecting said reversal valve means to said discharge side of said compressor, to the suction side of said compressor, and to the other side of said heat exchanger; and means including means responsive to the temperatures of the fluids at one of said connections of said condenser and at one of said connections of said evaporator, for sensing when the cooling load is greater than the heating load and when the heating load is greater than the cooling load, and for adjusting said reversal valve means to route discharge gas from said compressor to said other side of said heat exchanger when the cooling load is greater than the heating load, and for adjusting said reversal valve means to route gas from said other side of said heat exchanger to said suction side of said compressor when the heating load is greater than the cooling load.

14. A heat pump as claimed in claim 13 in which the connection of said one side of said heat exchanger to said refrigerant inlet of said evaporator includes refrigerant expansion valve means responsive to the temperature and pressure of the refrigerant at said one side of said heat exchanger.

15. A heat pump as claimed in claim 14 in which means is provided for preventing said expansion valve means from opening below a preset condensing temperature in said heat exchanger when said reversal valve means is adjusted to route discharge gas from said compressor to said heat exchanger, and in which means including means responsive to outdoor temperature is provided for disabling said means for preventing said expansion valve means from opening.

16. A heat pump for cooling indoor air in a portion of a building and simultaneously heating indoor air in another portion of the building, comprising a refrigerant compressor; a condenser for heating fluid for supply to local air heating units, said condenser having a fluid outlet connection and a fluid return connection; an evaporator for chilling fluid for supply to local air heating units, said evaporator having a fluid outlet connection and a fluid return connection; a surge drum; refrigerant lines connecting said compressor, condenser, evaporator and drum in a closed refrigerant circuit; said drum having a gas outlet connected to the suction side of said compressor; a heat sink exchanger; a pump for receiving liquid refrigerant from said drum; control means including means responsive to the temperatures of the fluid at one of said connections of said condenser and at one of said connections of said evaporator, for sensing when the cooling load is greater than the heating load and when the heating load is greater than the cooling load; means operated by said control means to route refrigerant from said compressor to said heat exchanger and to route liquid from said pump to said evaporator when the cooling load is greater than the heating load; and means operated by said control means for routing liquid from said pump to said heat exchanger and for routing refrigerant from said heat exchanger to said drum when the heating load is greater than the cooling load.

17. A heat pump as claimed in claim 16 in which said pump has driving means, in which the refrigerant outlet

of said evaporator is connected to a gas and unevaporated liquid inlet of said drum, and in which means including means responsive to the pressure of the refrigerant in the connection of said outlet of said evaporator to said inlet of said drum is provided for energizing said driving means.

18. A heat pump as claimed in claim **17** in which said heat exchanger is connected to said inlet of said evaporator for supplying liquid refrigerant to said evaporator when said heat exchanger is supplied with refrigerant from said compressor, in which expansion valve means responsive to the temperature and pressure of the refrigerant in the connection of said heat exchanger to said inlet of said evaporator is provided in said last mentioned connection.

19. A heat pump as claimed in claim **18** in which means is provided for preventing said expansion valve means from opening below a preset condensing pressure in said heat exchanger when said heat exchanger is supplied with refrigerant from said compressor, and in which means including means responsive to outdoor temperature is provided for disabling said means for preventing said expansion valve means from opening.

20. A heat pump as claimed in claim **16** in which said heat exchanger is connected to said inlet of said evaporator for supplying liquid refrigerant to said evaporator when said heat exchanger is supplied with refrigerant from said compressor, and in which expansion valve means responsive to the temperature and pressure of the refrigerant in the connection of said heat exchanger to said inlet of said evaporator is provided in said last mentioned connection.

21. A heat pump as claimed in claim **20** in which means is provided for preventing said expansion valve means from opening below a preset condensing pressure in said heat exchanger when said heat exchanger is supplied with refrigerant from said compressor, and in which means including means responsive to outdoor temperature is provided for disabling said means for preventing said expansion valve means from opening.

22. A heat pump for cooling indoor air in a portion of a building and simultaneously heating indoor air in another portion of the building, comprising a refrigerant compressor; a motor for driving said compressor; a condenser for heating fluid for supply to local air heating units; an evaporator for chilling fluid for supply to local air cooling units, a surge drum; refrigerant lines connecting said compressor, said condenser, said evaporator in a closed refrigerant circuit; a heat sink exchanger exposed to outdoor air; a fan for moving outdoor air over said heat exchanger; a pump for receiving liquid refrigerant from said drum; means for routing liquid from said pump to said heat exchanger and for routing gas and unevaporated liquid from said heat exchanger to said drum when the heating load is greater than the cooling load; and means for melting frost when it forms on said heat exchanger, including means for routing liquid from said pump to said condenser, including means for discontinuing the routing of liquid from said pump to said heat exchanger, including means for stopping said fan and compressor motors, and including means for routing liquid from said heat exchanger to said drum.

23. A heat pump as claimed in claim **22** in which a motor is provided for driving said pump, and in which means including means responsive to the refrigerant liquid level in said condenser is provided for energizing said last mentioned motor.

24. A heat pump for cooling indoor air in a portion of a building and simultaneously heating indoor air in another portion of the building, comprising a refrigerant compressor; a motor for driving said compressor; a condenser for heating fluid for supply to local air heating units; an evaporator for chilling fluid for supply to local air cooling units; a surge drum; reversal valve means; refrigerant lines connecting said compressor, said condenser, said evaporator, said drum and said reversal valve in a closed refrigeration circuit; a pump for receiving liquid refrigerant from said drum; a heat sink exchanger exposed to outdoor air; a fan for moving outdoor air over said heat exchanger; a motor for driving said fan; means when the heating load is greater than the cooling load for routing liquid from said pump to said heat exchanger, and including said reversal valve means for routing gas and unevaporated liquid from said heat exchanger to said drum; and means for melting frost when it forms on said heat exchanger, including means for stopping said fan and compressor motors, including means for discontinuing the routing of liquid from said pump to said heat exchanger, including means for routing liquid from said pump to said condenser, including said reversal valve means for routing gas from said condenser to said heat exchanger, and including means for routing liquid from said heat exchanger to said drum.

25. A heat pump as claimed in claim **24** in which a motor is provided for driving said pump, and in which means including means responsive to the refrigerant liquid level in said condenser is provided for energizing said last mentioned motor.

26. A heat pump for cooling indoor air in a portion of a building and simultaneously heating indoor air in another portion of the building, comprising a refrigerant compressor; a condenser for heating fluid for supply to local air heating units, said condenser having a fluid outlet connection and a fluid return connection; a first thermostat in one of said connections; an evaporator for chilling fluid for supply to local air cooling units, said evaporator having a fluid outlet connection and a fluid return connection; a second thermostat in one of said connections of said evaporator; a first potentiometer having a slider adjusted by said first thermostat; a second potentiometer having a slider adjusted by said second thermostat; means connecting said compressor, said condenser and said evaporator in a closed refrigeration circuit; a heat sink exchanger; a balancing relay having first and second windings, one end of said first winding being connected to one end of said first potentiometer, the other end of said first winding being connected to one end of said second potentiometer, one end of said second winding being connected to the other end of said first potentiometer, the other end of said second winding being connected to the other end of said second potentiometer; electric supply lines connected to said sliders; a first switch closed by said relay when the current through said first winding is larger than the current through said second winding; a second switch closed by said relay when the current through said second winding is larger than the current through said first winding; cooling control relay means having switches; heating control relay means having switches; means including said first switch for energizing said heating relay means; means including said second switch for energizing said cooling relay means; means for routing liquid refrigerant from said condenser to said heat exchanger, and for routing gas from said heat exchanger to said compressor; means including said switches of said heating relay means for energizing said last mentioned means; means for routing discharge gas from said compressor to said heat exchanger, and for routing liquid refrigerant from said heat exchanger to said evaporator; and means including said switches of said cooling relay means for energizing said last mentioned means.

27. A heat pump as claimed in claim **26** in which a third potentiometer is provided and which has a slider adjusted by said first thermostat; in which a fourth potentiometer is provided and which has a slider adjusted by said second thermostat; in which said supply lines are connected to said sliders of said third and fourth potentiometers; in which a second balancing relay is provided and which has third and fourth windings; means includ-

ing another switch of said heating relay means when said heating relay means is energized, for connecting one end of said third winding to one end of said third potentiometer; means including another switch of said heating relay means when said heating relay means is energized, for connecting one end of said fourth winding to the other end of said third potentiometer; means including another switch of said cooling relay means when said cooling relay means is energized, for connecting said one end of said third winding to one end of said fourth potentiometer; means including another switch of said cooling relay means when said cooling relay means is energized, for connecting said one end of said fourth winding to the other end of said fourth potentiometer; in which a fifth potentiometer is provided with its ends connected to the other ends of said third and fourth windings; in which a reversible motor having forward and reverse field windings, and having a rotor connected to move the slider of said fifth potentiometer, is provided; in which said second relay has a fifth switch which closes when the current through said third winding is larger than the current through said fourth winding, and has a sixth switch which closes when the current through said fourth winding is larger than the current through said third winding; means including said fifth switch for energizing one of said windings of said motor; means including said sixth switch for energizing the other one of said windings of said motor; in which said compressor has a plurality of loaders-unloaders; in which a plurality of switches, one for each of said loaders-unloaders, is provided with said switches of said plurality being arranged to be closed in succession when said rotor rotates in one direction, and to be opened in succession when said rotor rotates in the opposite direction; in which said loaders-unloaders are provided with solenoids for adjusting said loaders-unloaders to loading or unloading positions; and in which means including said last mentioned switches is provided for energizing said solenoids.

28. A heat pump for cooling indoor air in a portion of a building and simultaneously heating indoor air in another portion of the building, comprising a refrigerant compressor; a condenser for heating fluid for supply to local air heating units, said condenser having a fluid outlet connection and a fluid return connection; a first thermostat in one of said connections; an evaporator for chilling fluid for supply to local air cooling units, said evaporator having a fluid outlet connection and a fluid return connection; a second thermostat in one of said connections of said evaporator; a first potentiometer having a slider adjusted by said first thermostat; a second potentiometer having a slider adjusted by said second thermostat; means connecting said compressor, said condenser and said evaporator in a closed refrigeration circuit; a heat sink exchanger; a balancing relay having first and second windings, one end of said first winding being connected to one end of said first potentiometer, the other end of said first winding being connected to one end of said second potentiometer, one end of said second winding being connected to the other end of said first potentiometer, the other end of said second winding being connected to the other end of said second potentiometer; electric supply lines connected to said sliders; a first switch closed by said relay when the current through said first winding is larger than the current through said second winding; a second switch closed by said relay when the current through said second winding is larger than the current through said first winding; a reversible motor having forward and reverse field windings; means including said first switch for energizing one of said field windings; means including said second switch for energizing the other one of said field windings; third and fourth switches closed in succession when said one field winding is energized, and opened in succession when said other field winding is energized; a cooling control relay; a heating control relay; means including said third and fourth switches for energizing one of said control relays; means when said one control relay is energized, for deenergizing said other control relay; means including switches closed when said cooling relay is energized and including means energized when said last mentioned switches are closed, for routing discharge gas from said compressor to said heat exchanger, and routing liquid refrigerant from said heat exchanger to said evaporator; and means including switches closed when said heating relay is energized and including means energized when said last mentioned switches are closed, for routing liquid refrigerant from said condenser to said heat exchanger, and routing gas from said heat exchanger to said compressor.

29. A heat pump as claimed in claim **28** in which a third potentiometer is provided and which has a slider adjusted by said first thermostat; in which a fourth potentiometer is provided and which has a slider adjusted by said second thermostat; in which said supply lines are connected to said sliders of said third and fourth potentiometers; in which a second balancing relay is provided and which has third and fourth windings; means including another switch of said heating relay when said heating relay is energized, for connecting one end of said third winding to one end of said third potentiometer; means including another switch of said heating relay when said heating relay is energized, for connecting one end of said fourth winding to the other end of said third potentiometer; means including another switch of said cooling relay when said cooling relay is energized, for connecting said one end of said third winding to one end of said fourth potentiometer; means including another switch of said cooling relay when said cooling relay is energized, for connecting said one end of said fourth winding to the other end of said fourth potentiometer; in which a fifth potentiometer is provided with its ends connected to the other ends of said third and fourth windings; in which a second reversible motor having forward and reverse field windings is provided, said second motor having a rotor connected to move the slider of said fifth potentiometer; in which said second relay has a fifth switch which closes when the current through said third winding is larger than the current through said fourth winding, and has a sixth switch which closes when the current through said fourth winding is larger than the current through said third winding; means including said fifth switch for energizing one of said windings of said second motor; means including said sixth switch for energizing the other one of said windings of said second motor; in which said compressor has a plurality of loaders-unloaders; in which a plurality of switches, one for each of said loaders-unloaders, is provided with said switches of said plurality being arranged to be closed in succession when said rotor of said second motor rotates in one direction, and to be opened in succession when said rotor of said second motor rotates in the opposite direction; in which said loaders-unloaders are provided with solenoids for adjusting said loaders-unloaders to loading or unloading positions; and in which means including said last mentioned switches is provided for energizing said solenoids.

30. A heat pump for cooling indoor air in a portion of a building and simultaneously heating indoor air in another portion of the building, comprising a refrigerant compressor; a condenser for heating fluid for supply to local air heating units, said condenser having a fluid outlet connection and a fluid return connection; a first thermostat in one of said connections; an evaporator for chilling fluid for supply to local air cooling units, said evaporator having a fluid outlet connection and a fluid return connection, a second thermostat in one of said connections of said evaporator; a first potentiometer having a slider adjusted by said first thermostat; a second potentiometer having a slider adjusted by said second thermostat; means connecting said compressor, said condenser and

said evaporator in a closed refrigeration circuit; a heat sink exchanger; a balancing relay having first and second windings, one end of said first winding being connected to one end of said first potentiometer, the other end of said first winding being connected to one end of said second potentiometer, one end of said second winding being connected to the other end of said first potentiometer, the other end of said second winding being connected to the other end of said second potentiometer; electric supply lines connected to said sliders; a first switch closed by said relay when the current through said first winding is larger than the current through said second winding; a second switch closed by said relay when the current through said second winding is larger than the current through said first winding; means for routing liquid refrigerant from said condenser to said heat exchanger, and for routing gas from said heat exchanger to said compressor; means including said first switch, when closed, for energizing said last mentioned means; means for routing discharge gas from said compressor to said heat exchanger, and for routing liquid refrigerant from said heat exchanger to said evaporator; and means including said second switch, when closed, for energizing said last mentioned means.

31. A heat pump as claimed in claim 30 in which a third potentiometer is provided and which has a slider adjusted by said first thermostat; in which a fourth potentiometer is provided and which has a slider adjusted by said second thermostat; in which said supply lines are connected to said sliders of said third and fourth potentiometers; in which a second balancing relay is provided and which has third and fourth windings; means including switches closed when said first switch is closed for connecting one end of said third winding to one end of said third potentiometer and for connecting one end of said fourth winding to the other end of said third potentiometer; means including switches closed when said second switch is closed for connecting said one end of said third winding to one end of said fourth potentiometer and for connecting said one end of said fourth winding to the other end of said fourth potentiometer; in which a fifth potentiometer is provided with its ends connected to the other ends of said third and fourth windings; in which a reversible motor having forward and reverse field windings, and having a rotor connected to move the slider of said fifth potentiometer, is provided; in which said second relay has a third switch which closes when the current through said third winding is larger than the current through said fourth winding, and has a fourth switch which closes when the current through said fourth winding is larger than the current through said third winding; means including said third switch for energizing one of said windings of said motor, means including said fourth switch for energizing the other one of said windings of said motor; in which said compressor has a plurality of loaders-unloaders; in which a plurality of switches, one for each of said loaders-unloaders, is provided with said switches of said plurality being arranged to be closed in succession when said rotor rotates in one direction, and to be opened in succession when said rotor rotates in the opposite direction; in which said loaders-unloaders are provided with solenoids for adjusting said loaders-unloaders to loading or unloading positions; and in which means including said last mentioned switches is provided for energizing said solenoids.

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