May 20, 1969 W. K. KYLE ET AL 3,444,923

HEAT PUMPS WITH ELECTRIC BOOSTER HEATERS

Filed Jan. 2, 1968 Sheet 1 of 2

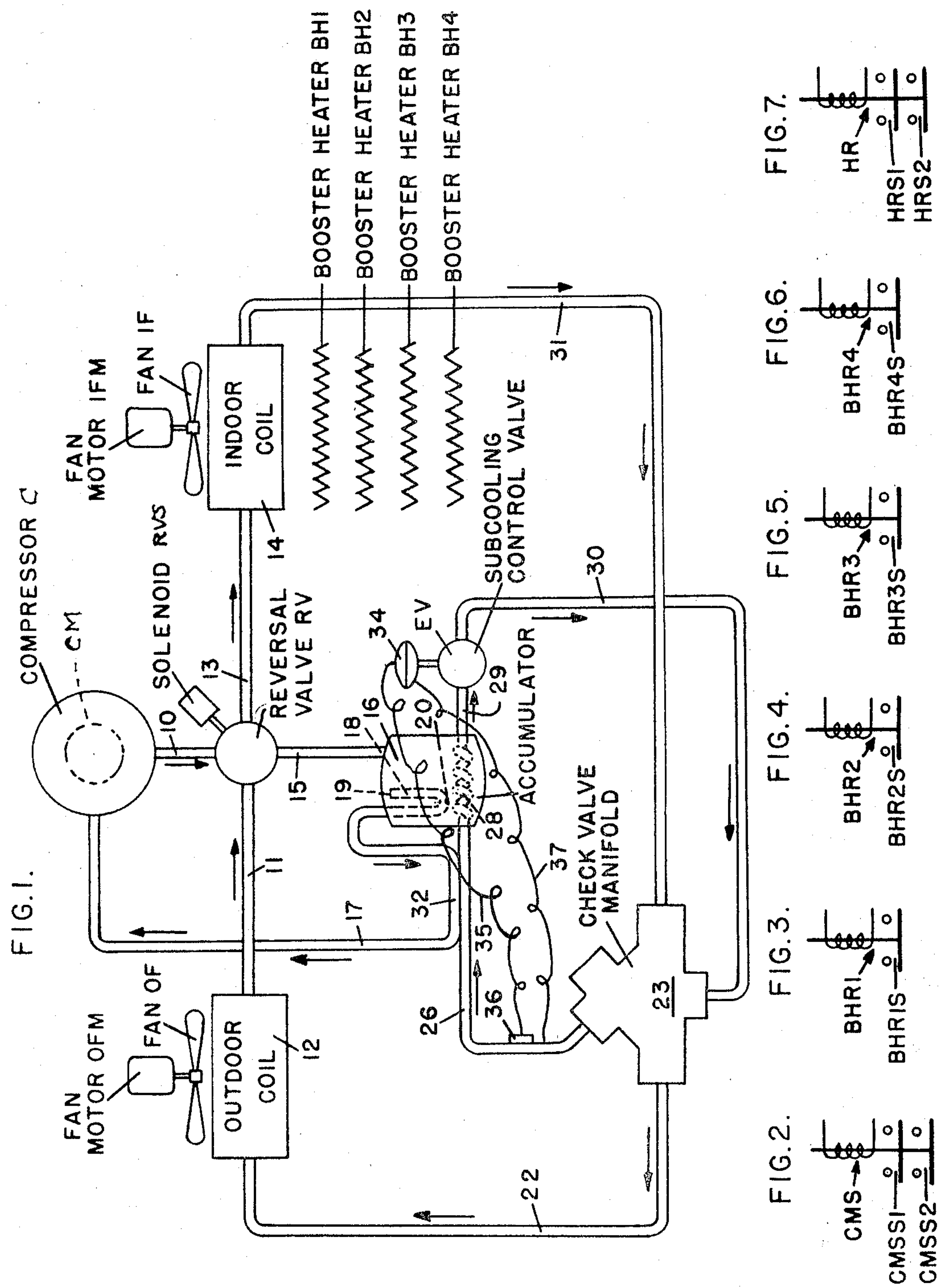

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FIG. 12.

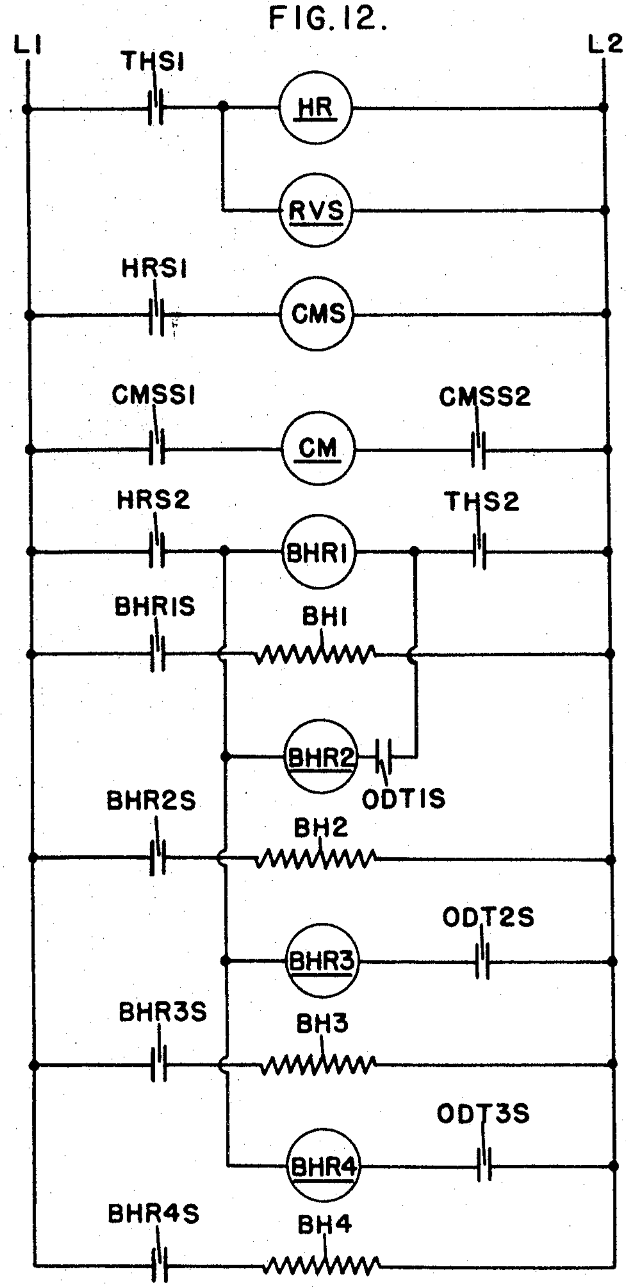


FIG. 8.

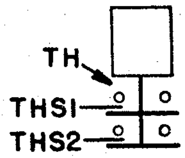


FIG. 9.

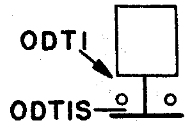


FIG. 10.

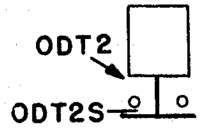
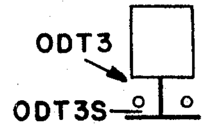


FIG. 11.



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HEAT PUMPS WITH ELECTRIC BOOSTER HEATERS

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U.S. Cl. 165—29 4 Claims

ABSTRACT OF THE DISCLOSURE

A heat pump has four electric booster heaters for adding heat to that from an indoor coil operating as a condenser coil, for heating indoor air when the outdoor temperature is low. An indoor heating control thermostat has two stages, the first one of which cycles the compressor of the heat pump. The second stage of the thermostat cycles the first booster heater, and cycles through a first outdoor thermostat, the second booster heater. The third and fourth booster heaters are cycled by second and third outdoor thermostats respectively.

Field of the invention

The field of the invention is heat pumps in which electric booster heaters are used to aid indoor coils operating as condenser coils, to heat indoor air when the outdoor temperature is low. Until the appearance of the heat pump disclosed in the U.S. Patent No. 3,264,837 of J. R. Harnish, heat pumps could be operated successfully for indoor air heating only in areas having mild winters where the outdoor temperature seldom decreases below about +15° F. Most of such heat pumps have booster heaters controlled as disclosed in the U.S. Patent No. 2,806,674 of G. L. Biehn, by a two stage indoor thermostat and outdoor thermostats. The first stage of the indoor thermostat cycles the compressor of the heat pump, and the second stage of the indoor thermostat together with the outdoor thermostats cycles the respective booster heaters.

The heat pump of the Harnish patent can be used to heat indoor air when the outdoor air is as low as —20° F., but the control system of the Biehn patent is not suited for it. The most serious fault of the Biehn control system when used with a Harnish heat pump, is that when the second stage of the indoor thermostat is satisfied, it turns off all of the booster heaters while the first stage of the indoor thermostat maintains the compressor in operation, with the fan of the indoor coil blowing heated air into the heated space. The compressor capacity is so reduced at very low outdoor temperatures that the temperature rise across the indoor coil is insufficient to prevent "cool" drafts with resultant discomfort. As an example, when the outdoor temperature is —10° F., the heating capacity of a heat pump may be approximately 12,000 B.t.u./hr., which with a 1200 c.f.m. movement of air by the indoor coil fan, produces approximately a 9° F. temperature rise across the indoor coil. With 70° F., or lower temperature return air, this will result in a "cool" draft. A second fault of the Biehn control system when used with a Harnish heat pump, is that the second stage of the indoor thermostat cycles all of the booster heaters on and off together. At about —15° F., the booster heaters represent about 85% of the total heating capacity. Switching 85% capacity on and off causes very wide temperature swings, and in addition, causes very large fluctuating loads on the electric power source.

This invention overcomes the faults of the Biehn control system when used with a Harnish heat pump, by cycling the third and fourth booster heaters of four stages of booster heaters with respective outdoor thermostats only. The first booster heater is cycled by the second stage of the indoor thermostat, and the second booster heater is cycled by an outdoor thermostat and the second stage of the indoor thermostat, to maintain indoor temperature. This still maintains the use of a compressor since the latter will not be cycled as long as booster heat is required.

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The improvement resulting from this invention is shown by the fact that when the second stage of the indoor thermostat is satisfied and turns off the first two booster heaters when the outdoor temperature is —15° F., the heat pump operates at a capacity of 12,000 B.t.u./hr. while the third and fourth booster heaters supply 32,800 B.t.u./hr. A total capacity of 44,800 B.t.u./hr. is provided with a temperature rise across the indoor coil and the third and fourth booster heaters of 34° F. so that there are no "cool" drafts. The load swing is 43% instead of 85%. This approximately 50% reduction in the load being cycled by the second stage of the indoor thermostat greatly reduces temperature swings, and maximum electric power.

Summary of the invention

A heat pump has four electric booster heaters. An indoor heating control thermostat has first and second stages. When the first stage of the thermostat calls for heat, it energizes a reversal valve solenoid which adjusts the reversal valve of the heat pump to its heating position; starts the compressor motor of the heat pump, and partially completes circuits for the energization of the booster heaters. Heat is provided by the indoor coil of the heat pump, operating as a condenser coil. If the heat provided by the indoor coil is insufficient, the second stage of the thermostat turns on the first booster heater. When the outdoor temperature decreases, for example, below 30° F., with the second stage of the thermostat calling for heat, the latter and a first outdoor thermostat together turn on the second booster heater. When the outdoor temperature decreases, for example, below 5° F., with the first stage of the indoor thermostat calling for heat, a second outdoor thermostat turns on the third booster heater. When the outdoor temperature decreases, for example, below —10° F., a third outdoor thermostat turns on the fourth booster heater if the first stage of the indoor thermostat is calling for heat.

Brief description of the drawings

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

FIG. 2 is a diagrammatic view of the starter of the compressor motor of the heat pump;

FIGS. 3–6 are diagrammatic views of the booster heat relays of the heat pump;

FIG. 7 is a diagrammatic view of the heat relay of the heat pump;

FIGS. 8–11 are diagrammatic views of the outdoor thermostats of the heat pump, and

FIG. 12 is a simplified circuit schematic showing how the electrical controls of the heat pump are connected.

Description of the preferred embodiment of the invention

Referring first to FIG. 1 of the drawings, a hermetic refrigerant compressor C, driven by an enclosed, electric motor CM, is connected by discharged gas tube **10** to reversal valve RV which is connected by tube **11** to outdoor coil **12**, and by tube **13** to indoor coil **14**. The valve RV is connected by tube **15** to the top of accumulator **16**. The accumulator **16** is connected by suction gas tube **17** to the suction side of the compressor C. The suction gas tube **17** has a U-shaped portion **18** within the accumulator **16**. The tube portion **18** has an open top **19** for the admission of gas, and has an oil bleed hole **20** in its bottom.

The outdoor coil **12** is connected by tube **22** to check-valve manifold **23** which is connected by liquid tube **26** to one end of coil **28** within the accumulator **16**. The other end of the coil **28** is connected by tube **29** to the inlet of subcooling control valve EV which is the expansion valve of the heat pump. The outlet of the valve EV is connected by tube **30** to the manifold **23**. The indoor coil **14** is connected by tube **31** to the manifold **23**.

The manifold **23** and its operation are fully described in the U.S. Patent No. 2,299,661 of J. R. Harnish and R. W. Ayling.

The liquid tube **26** has a portion in heat exchange contact with portion **32** of the suction gas tube **17**. The subcooling control valve EV has a diaphragm chamber **34**, the outer portion of which is connected by capillary tube **35** to thermal bulb **36** in heat exchange contact with the liquid tube **26** upstream of where the latter contacts the suction gas tube portion **32**. The inner portion of the chamber **34** is connected by capillary equalizer tube **37** to the interior of the tube **26**, although the valve EV could be internally equalized. The details of the valve EV and its operation are fully described in the previously mentioned Patent No. 3,264,837. The valve EV responds through the capillary tube **35** and the thermal bulb to the temperature of the refrigerant liquid, and responds through the tube **37** to the pressure of that liquid, and backs up sufficient liquid within the coil **12** or **14** operating as a condenser coil, to maintain a predetermined amount of subcooling of the liquid, which may be 10° F. subcooling at a condensing temperature of 100° F.

Outdoor air is blown by fan OF, driven by electric motor OFM, over the surface of the coil **12**. Indoor air is blown by fan IF over the surface of the coil **14**. Electric booster heaters BH1, BH2, BH3 and BH4 are located adjacent to and downstream with respect to air flow of the indoor coil **14**. The reversal valve RV is adjusted to its heating position by solenoid RVS when the latter is energized.

Referring now to FIGS. 2–11, starter CMS has switches CMSS1 and CMSS2 which close when the starter CMS is energized; booster heat relay BHR1 has switch BHR1S which closes when the relay BHR1 is energized; booster heat relay BHR2 has switch BHR2S which closes when the relay BHR2 is energized; booster heat relay BHR3 has switch BHR3S which closes when the relay BHR3 is energized; booster heat relay BHR4 has switch BHR4S which closes when the relay BHR4 is energized; heat relay HR has switches HRS1 and HRS2 which close when the relay HR is energized; indoor heating control thermostat TH has a first stage switch THS1 which closes at a predetermined indoor temperature, and has a second stage switch THS2 which closes at a lower indoor temperature; outdoor thermostat ODT1 has switch ODT1S which closes at a predetermined outdoor temperature; outdoor thermostat ODT2 has switch ODT2S which closes at a lower outdoor temperature; and outdoor thermostat ODT3 has switch ODT3S which closes at a lower outdoor temperature than that at which the switch ODT2S closes.

Referring now to FIG. 12, the heat relay HR shunted by the solenoid RVS, is connected in series with the first stage switch THS1 of the thermostat TH to electric supply lines L1 and L2. The compressor motor starter CMS is connected in series with the switch HRS1 to the lines L1 and L2. The motor CM is connected in series with the switches CMSS1 and CMSS2 to the lines L1 and L2. The booster heat relay BHR1 is connected in series with the switches HRS2 of the heater relay HR, and THS2 of the thermostat TH to the lines L1 and L2. The switch BHR1S of the booster heat relay BHR1 is connected in series with the first booster heater BH1 to the lines L1 and L2. The booster heat relay BHR2 is connected in series with the switch HRS2, the switch ODT1S of the first outdoor thermostat ODT1, and the switch THS2 to the lines L1 and L2. The switch BHR2S of the relay BHR2 is connected in series with the second booster heater BH2 to the lines L1 and L2. The booster heat relay BHR3 is connected in series with the switch HRS2, and the switch ODT2S of the second outdoor thermostat ODT2 to the lines L1 and L2. The switch BHR3S of the relay BHR3 is connected in series with the third booster heater BH3 to the lines L1 and L2. The booster heat relay BHR4 is connected in series with the switch HRS2, and the switch ODT3S of the third outdoor thermostat ODT3 to the lines L1 and L2. The switch BHR4S of the relay BHR4 is connected in series with the fourth booster heater BH4 to the lines L1 and L2.

The starters of the fan motors OFM and IFM are not shown since they would be energized when the compressor motor starter CMS is energized as is conventional.

The conventional indoor, cooling control thermostat is not shown since it and the circuits it controls are not related to this invention.

The cooling operation of the heat pump is not described since in it the controls of this invention are not used, and such operation is conventional and is that described in the previously mentioned Harnish Patent No. 3,264,837.

Heating operation

The arrows alongside the tubes of FIG. 1 show the direction of refrigerant flow during heating operation.

When the indoor thermostat TH calls for heat, it first closes its first stage switch THS1 which energizes the heater relay HR and the reversal valve solenoid RVS. The latter adjusts the reversal valve RV to its heating position. The switches HRS1 and HRS2 of the relay HR close. The closed switch HRS1 energizes the compressor motor starter CMS which closes its switches CMSS1 and CMSS2 which energize the compressor motor CM. The closed switch HRS2 connects the booster heat relays BHR1, BHR2, BHR3 and BHR4 to the line L1, partially completing their energizing circuits. The compressor C is started, and supplies discharge gas through the tube **10**, the valve RV, and the tube **13** into the indoor coil **14** to operate the latter as a condenser coil. Liquid from the coil **14** flows through the tube **31** into the manifold **23**, and from the latter through the tube **26** and the coil **28** within the accumulator **16** into the subcooling control valve EV operating as an expansion valve. Expanded refrigerant flows from the valve EV through the tube **30** into the manifold **23**, and from the latter through the tube **22** into the outdoor coil **12** to operate the latter as an evaporator coil. The valve EV overfeeds the coil **12** so that gas and unevaporated refrigerant liquid flow from the latter through the tube **11**, the valve RV and the tube **15** into the accumulator **16**. Gas separated from the liquid within the accumulator flows into the open top **19** of the U-shaped suction gas tube portion **18**, and through the suction gas tube **17** to the suction side of the compressor C. The fan motors IFM and OFM would be started when the compressor C starts, and would blow air over the coils **14** and **12** respectively.

The coil **28** within the accumulator **16** evaporates with heat from the high pressure liquid flowing through it, the refrigerant liquid flowing from the outdoor coil **12** into the accumulator **16**, the high pressure liquid being subcooled by this heat exchange. Any refrigerant liquid entering the suction gas tube **17** through the oil bleed hole **20** is evaporated by heat from the high pressure liquid flowing through the tube **26** where the latter contacts the suction gas tube portion **32**, the high pressure liquid being further subcooled by this heat exchange.

The indoor coil **14** operating as a condenser coil, heats the indoor air. If the heat from the coil **14** is insufficient, and the indoor temperature decreases below the set point of the first stage thermostat switch THS1, the second stage thermostat switch THS2 closes, and energizes through the closed switch HRS2 of the heater relay HR, the booster heat relay BHR1. The latter closes its switch BHR1S which energizes the first booster heater BH1. If the outdoor temperature decreases below, for example, 30° F., the switch ODT1S of the outdoor thermostat ODT1 closes, and energizes through the closed switches HRS2 and THS2, the booster heat relay BHR2. The latter closes its switch BHR2S, energizing the second booster heater BH2. If the outdoor temperature decreases below, for example, −5° F., the outdoor thermostat ODT2 closes its switch ODT2S, energizing through the closed switch HRS2, the booster heat relay BHR3 which closes its switch BHR3S which energizes the third booster heater BH3. If the outdoor temperature decreases below, for example, −15° F., the outdoor thermostat ODT3 closes its switch ODT3S which energizes through the closed switch HRS2, the booster heat relay BHR4 which closes its switch BHR4S, energizing the fourth booster heater BH4.

The second stage thermostat switch THS2 is not connected in the energizing circuits of the third and fourth booster heat relays BHR3 and BHR4 respectively, the latter being controlled only by the outdoor thermostats ODT3 and ODT4 respectively, while the first stage thermostat THS1 is closed and maintains the heater relay HR energized so that the switch HRS2 of the latter is closed. Thus, the second stage thermostat switch THS2 can cycle only the first and second booster heaters BH1 and BH2 respectively. This, as previously described, prevents "cool" drafts, greatly reduces temperature swings, and greatly reduces the maximum electric power load switched on and off.

We claim:

1. A heat pump comprising a compressor, an indoor coil connected to the discharge side of said compressor so as to operate as a condenser coil to heat indoor air, expansion means connected to said indoor coil, an outdoor coil connected to said expansion means and to the suction side of said compressor so as to operate as an evaporator coil, an indoor thermostat having a first stage switch and having a second stage switch, said second stage switch closing at a lower temperature than that at which said first stage switch closes, means including said first stage switch for starting said compressor, a first electric booster heater, means including said first and second stage switches for energizing said heater, a second electric booster heater, a first outdoor thermostat having a switch which closes at a predetermined outdoor temperature means including said first and second stage switches and said switch of said outdoor thermostat for energizing said second heater, a third electric booster heater, a second outdoor thermostat having a switch which closes at a lower temperature than that at which said switch of said first outdoor thermostat closes, and means including said first stage switch and said switch of said second outdoor thermostat but not including said second stage switch for energizing said third booster heater.

2. A heat pump as claimed in claim **1** in which there are provided a fourth electric booster heater, and a third outdoor thermostat having a switch which closes at an outdoor temperature lower than that at which said switch of said second outdoor thermostat closes, and in which means including said first stage switch and said switch of said third outdoor thermostat but not including said second stage switch is provided for energizing said fourth booster heater.

3. A heat pump comprising a compressor, an electric motor for driving said compressor, electric power connections, a starter for said motor having switching means for connecting said motor to said connections when said starter is connected to said connections, an indoor coil connected to the discharge side of said compressor so as to operate as a condenser coil to heat indoor air, expansion means connected to said indoor coil, an outdoor coil connected to said expansion means and to the suction side of said compressor so as to operate as an evaporator coil, an indoor thermostat having a first stage switch and having a second stage switch which closes at a lower temperature than said first stage switch, a heater relay having first and second switches which close when said relay is connected to said connections, means including said first stage switch for connecting said relay to said connections, means including said first switch of said relay for connecting said starter to said connections, a first electric booster heater, a first booster heat relay having a switch for connecting said heater to said connections when said first booster heat relay is connected to said connections, means connecting said second switch of said heater relay, said second stage switch and said first booster heat relay in series to said connections, a second electric booster heater, a second booster heat relay having a switch for connecting said second heater to said connections when said second booster heat relay is connected to said connections, a first outdoor thermostat having a switch which closes at a predetermined outdoor temperature, means connecting said second switch of said heater relay, said second stage switch, said switch of said outdoor thermostat and said second booster heat relay in series to said connections, a third electric booster heater, a third booster heat relay having a switch for connecting said third heater to said connections when said third relay is connected to said connections, a second outdoor thermostat having a switch which closes at a lower outdoor temperature than said switch of said first outdoor thermostat, and means connecting said second switch of said heater relay, said switch of said second outdoor thermostat, and said third relay to said connections.

4. A heat pump as claimed in claim **3** in which there are provided a fourth electric booster heater, a fourth booster heat relay having a switch for connecting said fourth heater to said connections when said fourth relay is connected to said connections, a third outdoor thermostat having a switch which closes at a lower outdoor temperature than said switch of said second outdoor thermostat, and means connecting said second switch of said heater relay, said switch of said third outdoor thermostat, and said fourth relay in series to said connections.

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