

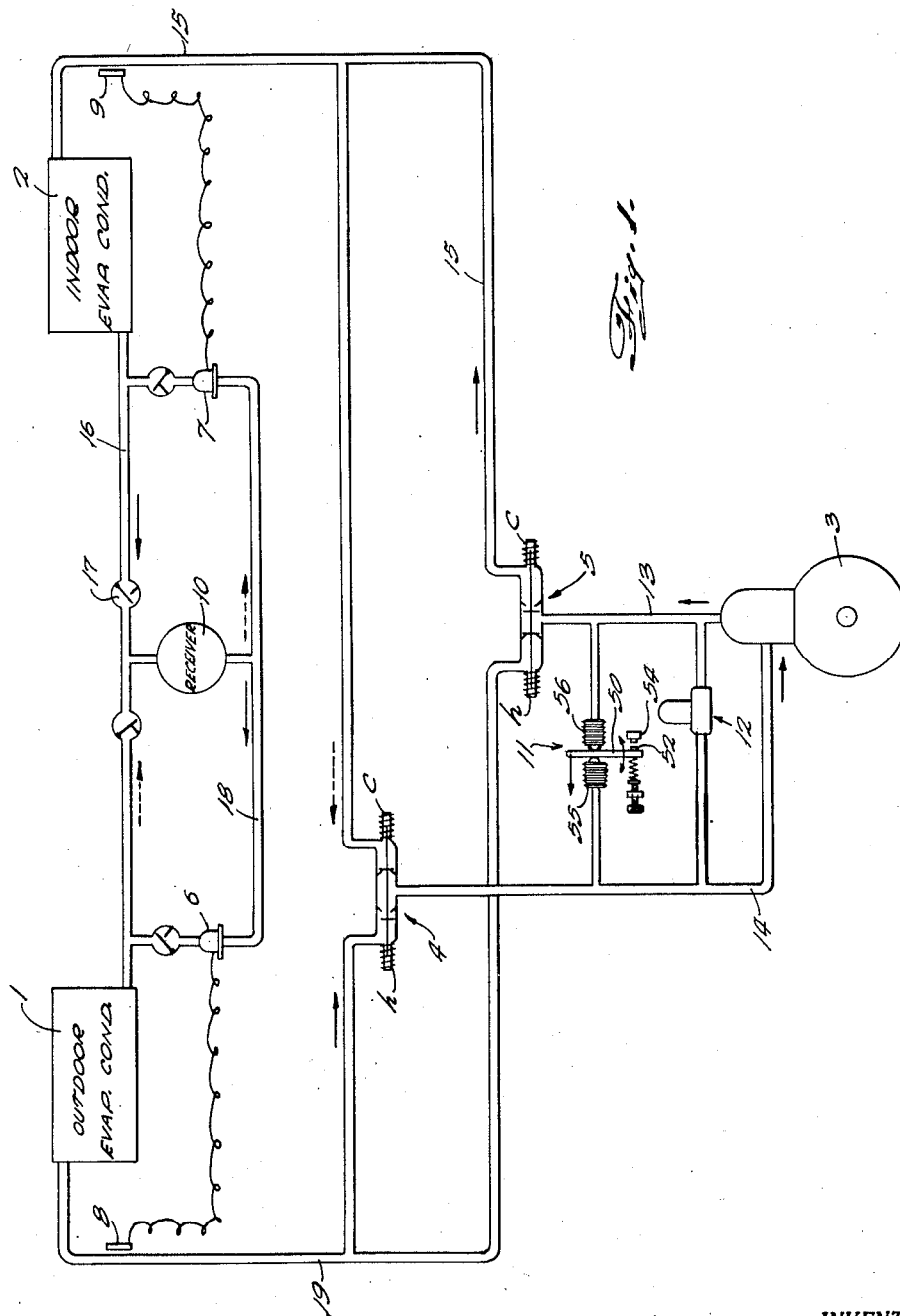
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HEAT PUMP SYSTEM

2,597,729

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3 Sheets-Sheet 1



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3 Sheets-Sheet 2

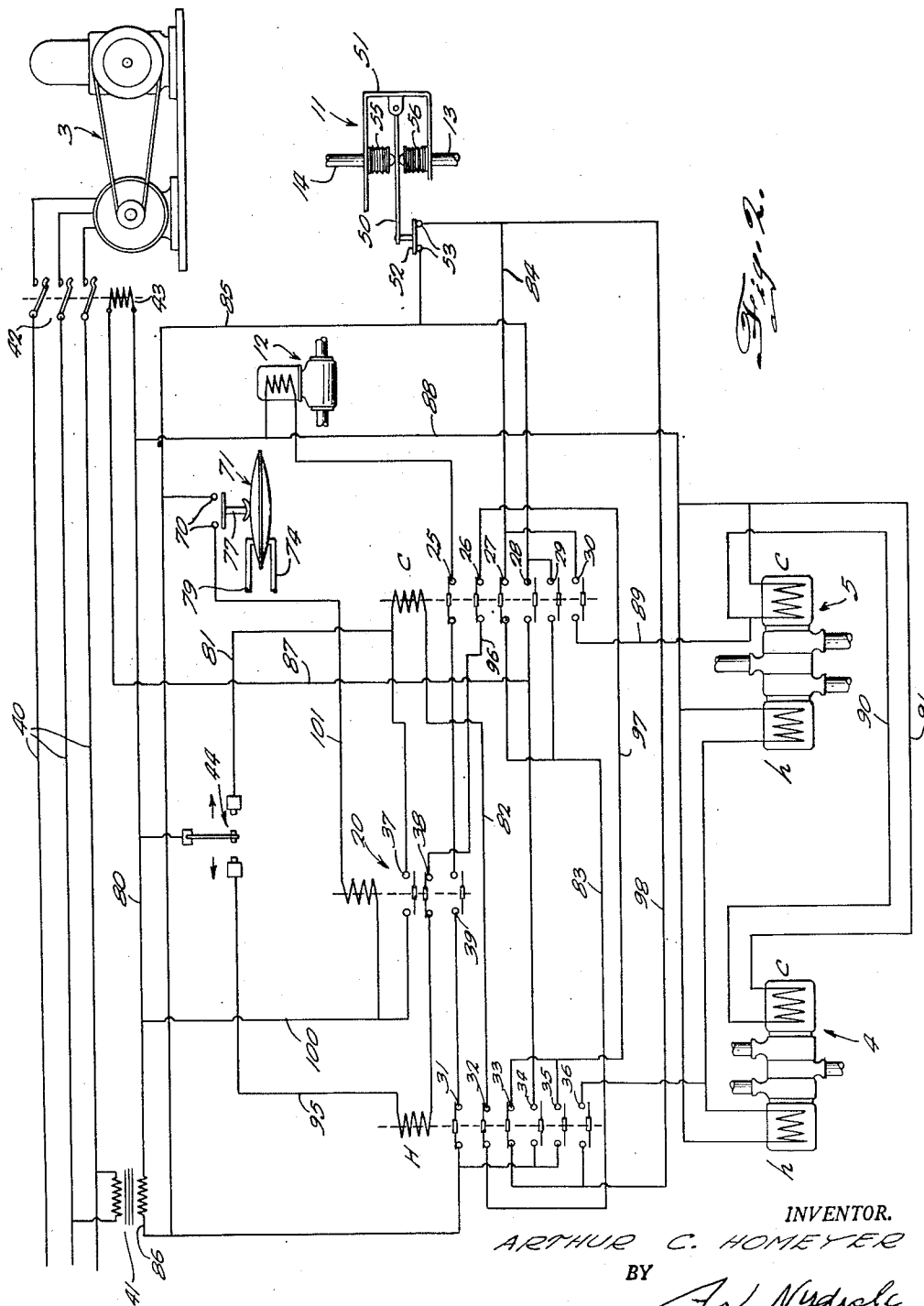


Fig. 2.

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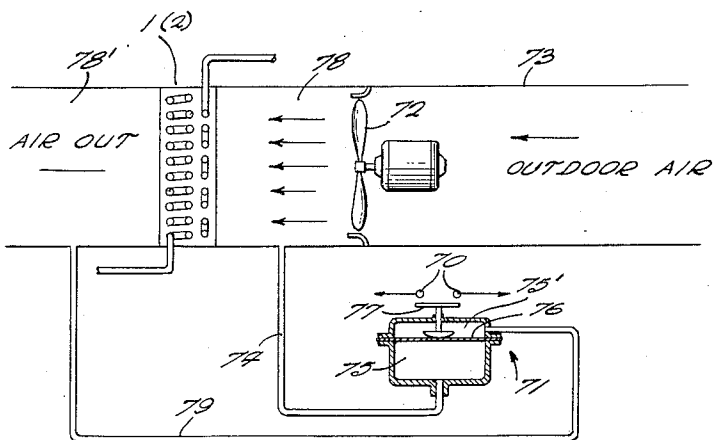
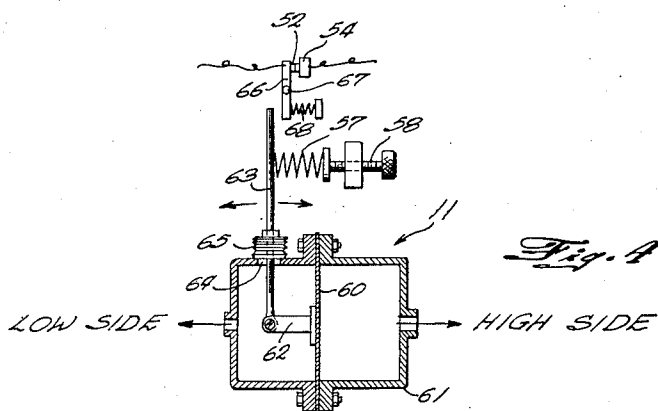
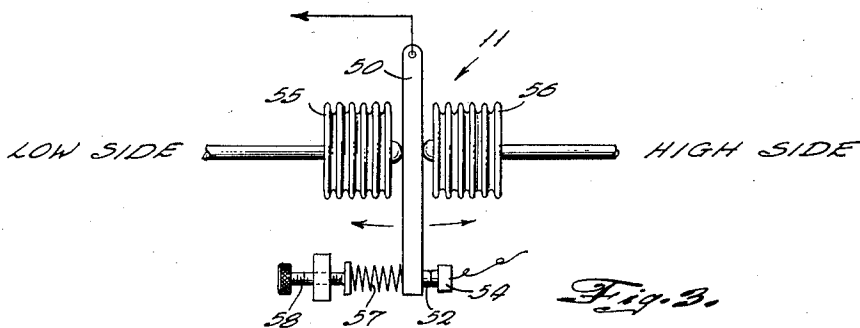
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HEAT PUMP SYSTEM

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10 Claims. (Cl. 62—6)

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This invention relates to heat pumps and more particularly to mechanical and electrical devices for controlling the reversal of the refrigerant cycle in a heat pump.

Heat pump systems of the general type, above referred to, generally comprise an outdoor heat transfer unit, an indoor heat transfer unit connected by a piping system and control valves with a compressor which forces a suitable refrigerant, such as methyl chloride or one of the refrigerants known as Freons, through the system. When the system operates in a cooling cycle the refrigerant is directed in gaseous form by the compressor first to the outdoor transfer unit, now operating as a heat dissipator or condenser, in which the refrigerant is liquefied and then through expansion valve means to the indoor transfer unit, now operating as a heat evaporator or absorber. In this latter unit the heat is absorbed and the refrigerant is again vaporized and flows back to the compressor. When the system operates in a heating cycle the flow direction of the refrigerant is reversed. As a result the compressor discharge of the refrigerant is first directed to the indoor transfer unit which now becomes a condenser or heat dissipator.

The direction of flow of the refrigerant from the discharge side of the compressor to the suction side is controlled in heat pump systems as herein referred to, by so-called switch-over or change-over valves which in turn are controlled manually or by temperature sensitive means such as a thermostat.

As will be apparent, pressure differentials are developed between the compressor discharge and suction sides during each operating cycle. They may be quite substantial and can readily reach approximately 200 pounds per square inch. As a result, an automatic shifting of the change-over valves from one position into the other is difficult under the aforementioned pressure conditions because the magnitude of the necessary port areas of the valves requires relatively large operating forces and offers considerable technical problems. When the compressor stops, these pressure differentials eventually equalize in a time interval, sometimes quite appreciable and depending upon the ambient temperatures.

There are known change-over valve designs employing power pistons, power diaphragms or motor operated constructions. However, the difficulty with the designs, as hitherto known, is that they are expensive and/or not reliable in operation. These aforementioned and related problems are so real that such heat pump systems are

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often equipped with manually operated change-over valves which must be operated by hand for each change from a heating cycle to a cooling cycle and vice versa.

One of the principal objects of the present invention is to provide control means which permit a completely automatic control of a heat pump system of the general type above referred to and a change of the system from one cycle to the other at will or in response to automatic temperature sensitive devices demanding such change.

Another object of the invention is to provide change-over valves which are relatively inexpensive, employ features commonly used and reliable in operation, remain in the existing valve position at the end of any cycle pending a repeat of the same cycle, and insure positive change-over when required.

Another object of the invention is to provide novel and improved change-over valves which are actuated by electromagnetic means including solenoids.

Another object of the invention, allied with the preceding one, is to provide pressure sensitive means which control the valve solenoids and the start of the compressor motor so that the solenoids are energized only when the pressure differential within the heat pump system has dropped below a predetermined low value. This has the advantage that comparatively small and low power solenoids can be employed to shift the valves and also that compressor motors with low starting torque can be used since due to the pressure reduction at the end of each cycle the compressor starts the next cycle against a low pressure or even at equalized pressure in the system.

Another more specific object of the invention, related to the preceding one, is to provide pressure sensitive means which are controlled by the pressure differential between the discharge side and the suction side of the compressor and which control the opening and closing of the energizing circuits of the valve solenoids.

Another object of the invention is to provide pressure equalizing means which serve to adjustably accelerate the decrease of the pressure differential at the end of each cycle. This has the advantage of shortening the off period between two cycles and thereby permitting the rapid initiation of a new cycle which may either be the same cycle or a reverse cycle.

Other and further features, objects, and advantages of the invention will be pointed out

hereinafter and set forth in the appended claims forming part of the application.

In the accompanying drawing several now preferred embodiments of the invention are shown by way of illustration and not by way of limitation.

Fig. 1 is a diagrammatic view of a reversible refrigeration system commonly known as a heat pump.

Fig. 2 is a typical circuit diagram for operating a heat pump according to Fig. 1.

Fig. 3 is a detail view of one of the components of the heat pump installation on an enlarged scale.

Fig. 4 is a sectional view of a modification of the component according to Fig. 3, and

Fig. 5 is a detail view of a form of control member for use in a heat pump control system of the type illustrated in Fig. 1.

Referring first to Fig. 1 in detail, the heat pump installation according to this figure comprises two heat exchangers 1 and 2 which are connected by suitable pipings to the suction and compression side, respectively, of a compressor 3. The compressor serves to pump a suitable refrigerant through the piping system and the heat exchangers. Heat exchanger 1 may be visualized as an outdoor heat transfer unit and heat exchanger 2 as an indoor heat transfer unit. Each heat exchanger acts either as evaporator for liquefied refrigerant or as condenser for vaporized refrigerant depending upon whether the installation is operated to heat or cool a conditioned space. The installation further comprises two so-called change-over, reversing or switch-over valves, generally designated by 4 and 5 respectively. These valves serve to control the direction of flow of the refrigerant through the system. In addition, the system is equipped with conventional expansion valves 6 and 7 respectively, sensing elements 8 and 9 of thermostats controlling the expansion valves, a receiver 10, and all other valves and devices customarily used in connection with installations of the general type here referred to.

The functioning of the installation as a heating or cooling system is determined by the setting of a room thermostat as will be more fully explained in connection with Fig. 2.

As was previously explained, the pressure differentials developed within an installation of the type here referred to are substantial during the operating cycle. It was further previously mentioned that as a result of these comparatively high differential pressures the operation of the change-over valves 4 and 5 offers considerable difficulties. According to the invention, these difficulties are eliminated or at least considerably reduced by providing a differential pressure switch generally designated by 11. As will be more fully explained hereinafter, this switch controls the operation of the change-over valves so that these valves will be moved from one position into the other only when the differential pressure is reduced to a magnitude which can be conveniently overcome by change-over valve actuators of comparatively small size and relatively low power. Switch 11 may be so adjusted that the change-over valves become operative only when the pressure within the system is approximately equalized or at least reduced to a predetermined low value.

Practical experience shows that under certain operating conditions an excessively long period of time elapses before the pressure differential

disappears or reaches the aforementioned low value and switch 11 can operate. To expedite the operation of switch 11 and hence the operation of the change-over valves 4 and 5, an equalizing valve, adjustable as to port or orifice opening, generally designated by 12, may be provided. As will be noted, differential pressure switch 11 and equalizing valve 12 are connected between a pipe 13 communicating with the pressure side of compressor 3 and a pipe 14 leading to the suction side of the compressor. The installation according to Fig. 1 is shown set for heating. Accordingly, the hot gas discharge of compressor 3 is directed through pipe 13, change-over valve 5 and a pipe 15 to the indoor heat exchanger 2 which now dissipates heat and acts as a condenser. The liquefied refrigerant then flows through a pipe 16, a now open valve 17, receiver 10, a pipe 18, expansion valve 6, the outdoor heat exchanger 1 in which the liquefied refrigerant is again evaporated, a pipe 19, change-over valve 4, and pipe 14 back to the suction side of the compressor.

When the installation is set for cooling, heat exchanger 1 operates as condenser and heat exchanger 2 as evaporator.

The hereinbefore described function of the installation is conventional. It is therefore believed that a more detailed description is not essential for the understanding of the invention.

Change-over valves 4 and 5 are solenoid operated valves the solenoids of which can be of comparatively small size since, as previously explained, the valves become operative only when the pressure differential within the system has completely or nearly disappeared. Equalizing valve 12, being of relatively small orifice size, is also solenoid operated and is conventionally used for this type of service.

The energizing circuits of the various valve solenoids will now be explained in connection with Fig. 2. This figure shows the valve circuits in detail. The circuit diagram further shows a defrost relay generally designated by 20 which is controlled by the icing conditions at the heat exchanger coil of one of the heat exchangers.

As can be seen on Figs. 1 and 2, each change-over valve has two solenoid coils *c* and *h*, each coil *c* serving to place the respective change-over valve in a position for a cooling cycle and each coil *h* serving to place the respective valve in a position for a heating cycle. The coils *c* are controlled by a relay C and the coils *h* by a relay H. The relay C is provided with six pairs of contacts 25, 26, 27, 28, 29, and 30, which are controlled by six contact arms. The relay contacts and the said arms are so arranged that contacts 25, 26, and 27 are closed, and contacts 28, 29, and 30 are open when the relay is deenergized, and that contacts 28, 29, and 30 close just before contacts 25, 26, and 27 open when the relay is energized. Similarly, relay H is shown as being equipped with six pairs of contacts 31, 32, 33, 34, 35, and 36, of which contacts 31, 32, and 33 are closed, and contacts 34, 35, and 36 are open when relay H is deenergized. The opening of contacts 31, 32, and 33 occurs slightly after contacts 34, 35, and 36 are closed.

Relay 20 is equipped with three sets of contacts 37, 38, and 39, of which contacts 37 and 39 are open and contact 38 is closed when relay 20 is deenergized. Contacts 37 are in the energizing circuit of relay C, contacts 38 are in the energizing circuit of relay H, and contacts 39 are connected in series with contacts 25 and 31.

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The entire control system is supplied with current from power lines 40 through a transformer 41, compressor motor 3 being connected directly by a switch 42 to the power lines. The switch is controlled by a magnet coil 43.

The control system further comprises a room thermostat 44 of conventional design, the movable contact of which can make contact with either one of two stationary contacts to close a heating or a cooling circuit, as will be more fully explained hereinafter.

The differential pressure switch 11, as shown in Figs. 1, 2, and 3, comprises a pivotal contact arm 50 which may be pivoted to a frame 51 as is shown in Fig. 2. Contact arm 50 has thereon a contact 52 coacting according to Fig. 2 with a pair of contacts 53 and according to Figs. 1 and 3 with a contact 54. According to Figs. 2 and 3, arm 50 is pivoted between two bellows 55 and 56, bellows 56 communicating with the pressure side of the compressor through pipe 13 and bellows 55 with the suction side through pipe 14. As will be apparent, the position of arm 50 is controlled by the differential pressure conditions affecting the two bellows. The arrangement is so that contacts 52, 54 and 52, 53, respectively, are closed when the pressure differences in the entire system are approximately equalized or within the limits at which the change-over valves 4 and 5 have been designed to operate. The operational pressure of switch 11 may be conveniently adjusted by means of a spring 57, the tension of which can be adjusted by a set screw 58.

Fig. 4 shows a modification of the differential pressure switch 11. According to this figure, the two bellows 55 and 56 are replaced by a diaphragm 60 forming a partition wall within a housing 61. One side of this housing communicates with the pressure side of the compressor and the other with the suction side so that diaphragm 60 is deflected according to the pressure difference on opposite sides of the diaphragm. Diaphragm 60 supports a post 62 to which is linked a bar 63. This bar guided through an elongated opening 64 of housing 61 by means of a bellows 65 so that bar 63 can pivot to a certain extent about its connection at bellows 65 in response to a deflection of diaphragm 60. Bar 63 coacts with a contact arm 66 pivotal about a pivot 67. Arm 66 supports contact 52 which is biased toward engagement with contact 54 by a loaded spring 68. The arrangement is again so that contacts 52 and 54 are closed when the pressure on both sides of the diaphragm is equalized or within the aforementioned limits.

The equalizing valve 12 is of conventional design. It is connected similarly to switch 11 between the pressure and the suction side of the compressor and serves to accelerate the drop of the pressure difference within the system at the end of a heating or cooling cycle so that the change-over valves can operate under the control of switch 11. Valve 12 is operated by means of a solenoid coil. The energizing circuit of valve coil is controlled by the defrost relay 20.

The energizing circuit of the defrost relay 20 is controlled by the air flow through a duct 73 in which the windings of the coil of one of the heat exchangers 1 or 2, preferably exchanger 1, are disposed. As a result of the air flow across the coil, a certain pressure difference will develop in the spaces on opposite sides of the coil, depending upon the areas of the passageways between the windings of the coil. This pressure difference is

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used to control a pressure sensitive device, generally designated by 71, which in turn controls the defrost relay 20. The device is shown as comprising a casing including two chambers 75 and 75' separated by a diaphragm 76. The space 78 on one side of the coil communicates through a pipe 74 with space 75 and the space 78' on the opposite side of the coil communicates through a pipe 79 with the space 75'. A contact 77 engageable with contacts 70 abuts against diaphragm 76 and is so arranged that contacts 70 and 77 are disengaged when the windings of the coil of the heat exchanger are not or only comparatively slightly coated with ice. When the coil windings become more and more heavily coated with ice the passageways between the coil windings are correspondingly decreased. As a result, the pressures within the spaces 78 and 75 increase, and the pressures within the spaces 78' and 75' decrease, resulting in a deflection of diaphragm 76 into the space 75' until finally contacts 70 and 77 engage each other, thereby energizing relay 20.

It will be evident that instead of sensing the icing conditions at the heat exchanger by the areas of the said passageways, other suitable sensing means may be employed; for instance, a feeler may be provided which probes the thickness of the ice coating. It is also sometimes practical and advisable to provide a timing device which closes contacts 70 and 77 at selected intervals for a predetermined period of time.

The system, as hereinbefore described, operates as follows:

Let it be assumed that for the purpose of initiating a cooling cycle the movable contact arm of thermostat 44 engages the cooling contact (right-hand contact), then an energizing circuit is closed for relay C from a supply lead 80 through a lead 81, the coil of relay C, a lead 82, contacts 32, a lead 83, contacts 27, a lead 84, contacts 53, 52, a lead 85, and back to a supply lead 86. As a result, relay C closes contacts 28, 29 and 30 and opens contacts 25, 26 and 27 after closing the aforementioned contacts. The closing of contacts 29 establishes a holding circuit from supply line 80 through the respective contact of thermostat 44, lead 81, the coil of relay C, contacts 32, lead 83, contacts 29, and back through lead 85 to supply line 86. The closing of contacts 28 completes a circuit for the coil 43 of switch 42 from the supply line 80, the switch coil 43, a lead 87, contacts 28 and back through lead 85 to supply line 86. As a result, switch 42 closes and connects the motor of compressor 3 to the power lines 40 so that the compressor becomes operative. Simultaneously, contacts 30 close energizing circuits for the cooling coils c of the change-over valves 4 and 5. These circuits extend from supply line 80 through a lead 88, coil c of valve 5, a lead 89, contacts 30, lead 84, back to supply line 86 as previously described. Coil c of change-over valve 4 is connected in parallel to coil c of valve 5 by leads 90 and 91. As a result, coils c of the change-over valves move the same from the heating positions shown in Fig. 1 to the cooling positions. As to the various conventional valves shown in the piping system of Fig. 1, it is assumed that the said valves are placed in the proper positions by conventional means, a detailed description of which does not appear to be essential to the understanding of the invention.

During the hereinbefore described cycle, a considerable pressure difference will be developed between the pressure side and the suction side of

the compressor. As a result, one of the bellows of switch 11 will be expanded and the other be compressed so that contacts 52, 53 are disengaged. Consequently, the circuit of coils *c* is interrupted at contacts 53 but the energizing circuit of the relay C remains closed by reason of the previously described holding circuit over the contacts 29.

Let it now be assumed that all the components of the circuit system are in the position shown in Fig. 2 and that thermostat 44 engages its heating contact, thereby initiating a heating circuit. As a result, the coil of relay H is now energized from power supply line 80, the respective contact of thermostat 44, a lead 95, the coil of relay H, contacts 38, a lead 96, contacts 26, a lead 97, contact 33, a lead 98, and through contacts 53 and 52, and lead 85, back to supply line 86. Consequently, relay H attracts its contact arms setting up circuits for motor switch 42 and heating coils *h* of the change-over valves 4 and 5, which circuits can be conveniently traced from the previous description. Contacts 53 will again be opened when compressor 3 starts due to the pressure differentials developed during the heating cycle.

As will appear from the previous description, neither a cooling cycle or a heating cycle can be initiated by thermostat 44 unless contacts 52 of switch 11 close contacts 53. In other words, a change-over from one cycle to the other is not possible as long as there is a pressure differential in the system higher than the one for which the differential pressure switch 11 is adjusted. It will be obvious that immediately following the completion of either running cycle, the internal pressures of the system tend to equalize. It will now be apparent that for a certain period of time neither a heating cycle nor a cooling cycle is in operation. If this "off cycle" is of sufficient duration, the internal pressure of the system eventually reaches approximate equalization, contacts 53 close and a new cycle begins when the thermostat demands it.

As previously described, this arrangement has the advantage that the solenoids of the change-over valves do not have to overcome any substantial pressure and can, hence, be of comparatively small size and power. Furthermore, the solenoids of the change-over valves can be designed for intermittent duty.

Let it now be assumed that the system is operating in a heating cycle, that is, the contact arm of thermostat 44 engages the heating contact and relay H is energized as previously described. Let it further be assumed that the icing condition at the respective heat exchanger coil is such that contact 77 closes contacts 70 as described in connection with Fig. 5. As a result, an energizing circuit is closed for the coil of relay 20 which can be traced from supply line 80 through a lead 100, the coil of relay 20, a lead 101, contacts 70 and 77, lead 85, back to supply line 86. As a result, relay 20 closes its contacts 37 and 39 and opens its contacts 38. The opening of contacts 38 interrupts the energizing circuit of relay H which becomes deenergized and returns its contact arms into the position shown in Fig. 2. The closing of contacts 39 of relay 20 and 31 of relay H establishes an energizing circuit for the coil of equalizing valve 12. This valve, as previously explained, serves to equalize more rapidly the pressure differences in the system so that the differential pressure switch 11 can close contacts 53. The closing of contacts 37 of relay 20 establishes an energizing circuit for the coil of relay C. This circuit is independent

of thermostat 44 and may be traced from supply line 80 through lead 100, contacts 37, coil of relay C, lead 82, contacts 32 now closed, lead 83, contacts 27, lead 84, contacts 53 now closed, and lead 85, back to supply line 86. Consequently, relay C reverses the flow direction of the refrigerant, as previously described, so that the heavy ice formations on the respective heat exchanger coil are removed or at least reduced, contacts 70 are opened again, relay 20 becomes deenergized and the entire system again functions under the control of thermostat 44.

While the invention has been described in detail with respect to certain now preferred examples and embodiments of the invention it will be understood by those skilled in the art after understanding the invention, that various changes and modifications may be made without departing from the spirit and scope of the invention, and it is intended, therefore, to cover all such changes and modifications in the appended claims.

What is claimed as new and desired to be secured by Letters Patent is:

1. A heat pump of the type including compressor means, a pair of heat exchanger means, and change-over valve means connected by piping means in a reversible refrigerant cycle system, in combination with electromagnetic means associated with said change-over valves for shifting the same from the heating cycle position into the cooling cycle position and vice versa in response to an energization of the electromagnetic means, pressure sensitive means connected with the piping means and responsive to internal pressure differentials in the system, and switch means controlled by said pressure sensitive means and connected in circuit with said electromagnetic means for controlling the energization thereof, the said pressure sensitive means being arranged to set the switch means for energization of the electromagnetic means only when the said pressure differentials within the piping means are below a predetermined value.
2. A heat pump as defined in claim 1, wherein said pressure sensitive means communicate with the pressure side and the suction side of the compressor means, and wherein said switch means controlled by the pressure sensitive means are included in an energizing circuit with said electromagnetic means, the said pressure sensitive means being set and arranged to actuate said switch means in response to a pressure difference between the pressure side and the suction side of the compressor means below said predetermined value.
3. In a heat pump, in combination electrically controlled compressor means, a pair of heat exchanger means, change-over valves including solenoids for shifting the valve means from one position into the other by energization of the respective solenoids, piping means connecting the aforesaid components of the pump in a reversible refrigerant cycle system, thermostat means including control contacts for initiating a cooling or a heating cycle, first relay means controlling the solenoids of the change-over valve means for shifting the latter into the position for a heating cycle and controlling the actuation of the compressor means, second relay means controlling the solenoids of the change-over valve means for shifting the latter into the position for a cooling cycle and controlling the actuation of the compressor means, circuit means connecting said thermostat contacts and said relay means in an

energizing circuit for energizing the respective relay means in response to the closing of the respective thermostat contact, and pressure sensitive means responsive to pressure differentials in said piping means and comprising switch contacts included in said circuit means, said pressure sensitive means being arranged to actuate their switch contacts only when the pressure differentials within the piping means are below a predetermined value.

4. A heat pump as defined in claim 3, wherein each of said relay means controls a holding circuit for its coil by-passing said switch contacts of the pressure sensitive means, each of said holding circuits being closed upon energization of the respective relay means.

5. A heat pump as defined in claim 1, in combination with equalizing valve means included in said piping means between the pressure side and the suction side of the compressor means and arranged to accelerate the drop of the pressure differential in the piping means at the end of each cycle, and electro-mechanical actuating means controlled by the operational condition at one of the heat exchanger means at the end of each cycle and controlling the operation of said equalizing valve means.

6. A heat pump as defined in claim 5, wherein said electro-mechanical actuating means comprise sensing means sensing the icing conditions at one of the heat exchangers, switch means controlled by the sensing means in accordance with the said icing conditions, and relay means controlled by the switch means of the sensing means and controlling the aforesaid circuit means so as to cause, when actuated, the respective one of the relay means included in the said circuit to shift the change-over valve means into the position for a heating cycle.

7. A heat pump as defined in claim 6, wherein one of said heat exchangers is disposed within a duct for passing a fluid across the said heat exchanger, and wherein said sensing means comprises a closed housing, a diaphragm means therein so as to form two chambers within the housing, and conduit means connecting duct portions on opposite sides of the said heat exchanger with said chambers for varying the deflection of the diaphragm means by the pressure difference in said chambers as caused by the flow of a fluid

through said duct and across the said heat exchanger, said switch means of the sensing means being controlled by the deflection of the diaphragm means.

8. A heat pump as defined in claim 7, wherein the said heat exchanger includes heat dissipating components subject to the formation of ice coating thereon during operation, the passage areas between the said components, as determined by an ice coating, controlling the pressure difference on opposite sides of the said heat exchanger.

9. A heat pump as defined in claim 1, wherein said pressure sensitive means connected with piping means comprise a movable member, conduit means transmitting the pressure at the discharge side of the compressor means to one side of the movable member, and conduit means transmitting the pressure at the suction side of the compressor means to the opposite side of the movable member, the position of the said movable member being controlled by the pressure difference between the two sides of the compressor means; and wherein said switch means comprise relatively movable contact means, the relative position of the said contact means being controlled by the position of said movable member so as to set said switch means for energization of the electromagnetic means when the movable member is in a position corresponding to a pressure differential below said predetermined value.

10. A heat pump as defined in claim 9, wherein the said pressure sensitive means comprise two bellows, one communicating with the pressure side of the compressor means and the other with the suction side, each of said bellows being in operative engagement with said movable member, the position of the said member being controlled by the relative expansion and contraction of said bellows.

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