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CONTROL SYSTEM FOR REVERSE CYCLE REFRIGERATION MACHINES

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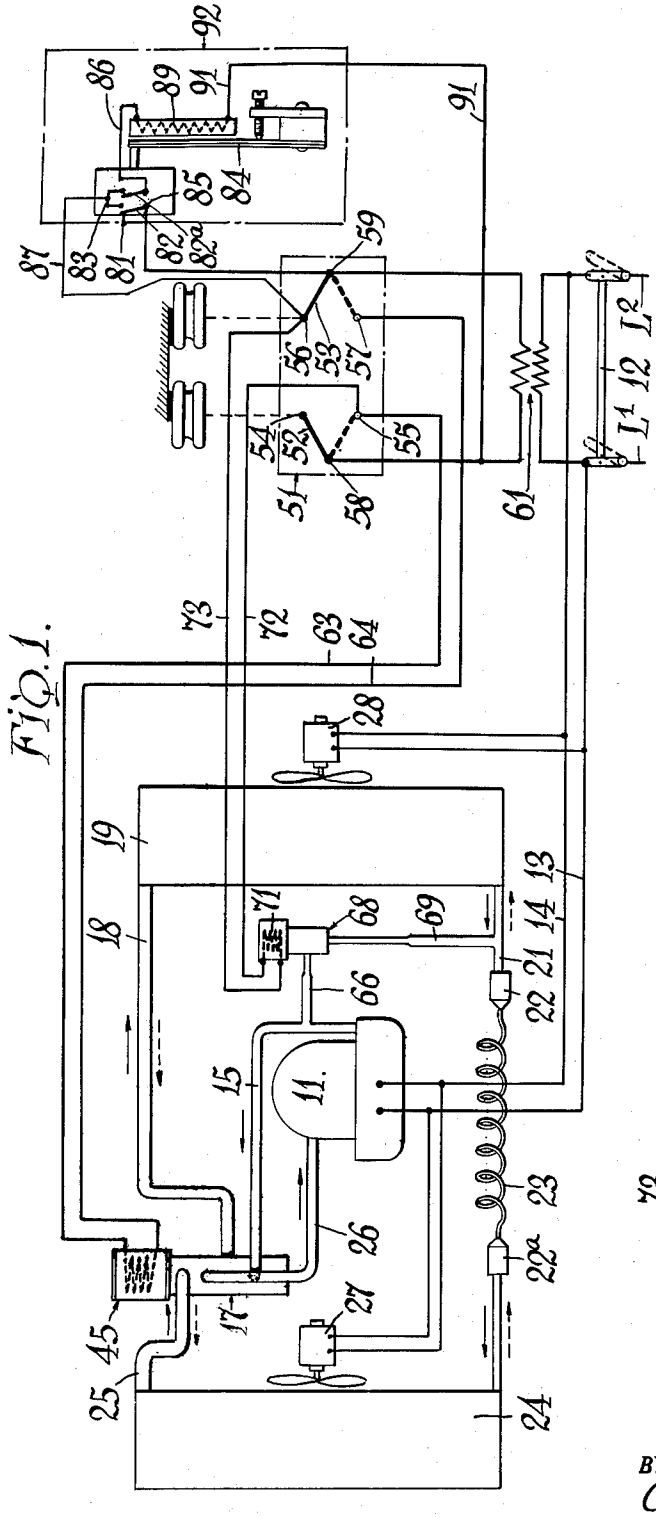


Fig. 1.

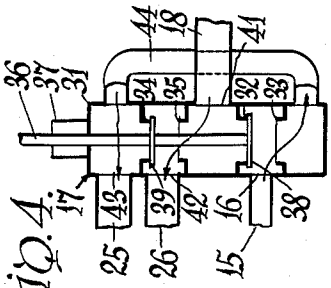


Fig. 4.

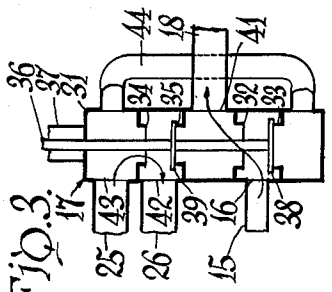


Fig. 3.

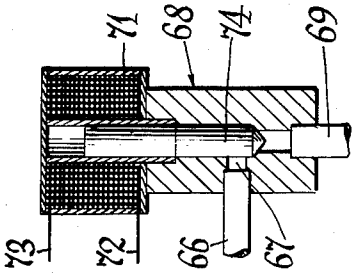


Fig. 2.

INVENTOR.
Julius S. Rosen,
BY
ATTORNEY.

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CONTROL SYSTEM FOR REVERSE CYCLE REFRIGERATION MACHINES

Julius S. Rosen, Buffalo, N. Y., assignor to Fedders-Quigan Corporation, Buffalo, N. Y.

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3 Claims. (Cl. 62—4)

This invention relates to refrigeration machines of the type wherein the flow of refrigerant may be reversed between the coils serving selectively the functions of a condenser and an evaporator, and it has particular reference to the provision of control instrumentalities associated with the customary components of a refrigeration machine, whereby the operation may be made automatic and responsive to the thermal condition existing both in an enclosure to be conditioned and to exterior atmospheric conditions.

In the well known reverse cycle refrigeration machine, there is usually provided a heat exchange coil within an enclosure, and another heat exchange coil outside of the enclosure, the inside coil constituting an evaporator and the outside coil constituting a condenser when it is desired to cool the air in the enclosure. Conversely, when it is desired to warm the room air, the functions of the two coils are interchanged, so that the heat of the compressed refrigerant becomes available to the room air, while the heat absorbed by the refrigerant volatilized in the outside coil may be ultimately transferred to the inside, in accordance with the well known principle of the heat pump.

The present invention is concerned with the provision of a control for a reverse cycle refrigeration machine, wherein, by means of thermostats located in the enclosure to be conditioned, and suitable control valves in the refrigeration circuit, the functions of the inside and outside coils as either evaporator or condenser are determined by the temperature existing in the enclosure. Additionally, provision is made to operate the refrigerant compressor continuously to minimize repetitious surges of high starting current through the electric power supply lines, a condition which is now present with machines operating cyclically or intermittently. Likewise, provision is made to protect the outside coil from frost accumulations when it serves as the evaporator, such frost accumulations tending to occur during relatively cold weather when the need exists for heating the room air.

It may be prefatorily noted that the present invention is applicable to machines now commonly called "room air conditioners," which may be wholly self-contained or "packaged" units, which have come into vogue during the past score of years, primarily for the comfort cooling of residential or office rooms. The popularity of such units has led to increasing efforts to incorporate the heat pump principle in them, so that the same equipment could be employed to heat the room air, particularly during seasonal changes when a limited amount of added heat is indicated, but not so much as to warrant starting a central heating plant. A machine having sufficient capacity to supply adequate heat under these conditions usually draws so much electric current, upon starting the compressor motor, as to adversely affect other electrical appliances which may be in the same building. For example, the lights flicker, radio and television reception is impaired, and line fuses may blow if there is appreciable

current demand already existing in the supply line. Accordingly, in the preferred embodiment of the invention, provision is made for continuous operation of the compressor over long periods of time, which also leads to a simplified automatic control system.

The invention is illustrated in the accompanying drawing, wherein:

Fig. 1 is a diagram of the refrigeration and electrical control circuits;

Fig. 2 is a section through a solenoid operated control valve utilized to interrupt the normal functioning of the coil then serving as the evaporator; and

Figs. 3 and 4 are sections through a four-way reversing valve utilized to interchange the functions of the inside and outside coils, with the valve elements in alternate positions.

As shown in Fig. 1, a hermetic motor-compressor **11** is operated by current supplied through line wires **L1** and **L2** and manually controlled line switch **12** and branch lines **13** and **14**. The refrigerant discharge line **15** from the compressor leads to one port **16** of a four-way valve **17**, and it may initially be assumed that the compressed refrigerant flows through the valve **17** into a line **18** leading to the "outside" coil or heat interchanger **19**, which therefore is now functioning as a refrigerant condenser. The condensed refrigerant flows through a line **21** and strainer **22** to a capillary tube **23** or other metering element, and thence through a strainer **22*a*** into the "inside" coil **24**, now functioning as an evaporator. The outlet side of the coil **24** is connected by a line **25** to another port of the valve **17**, which is then in communication with a fourth valve port coupled to a suction line **26**, leading to the intake side of the compressor **11**. The circuit as just described is a typical or conventional circuit for cooling the area in which the coil **24** is located. Forced air circulation through the coils is provided by motor-driven fan units **27** and **28**, here shown as connected in parallel to the compressor **11**, and therefore running whenever the switch **12** is closed.

One form of reversing valve **17** is shown somewhat schematically in Figs. 3 and 4. A valve body **31** is provided with a pair of spaced valve seats **32** and **33** of relatively large area, and a second pair of seats **34** and **35** of less area. A valve stem **36** extends into the body **31** and also into a sealed cap **37** at one end thereof, and the stem carries a pair of disc valves **38** and **39**, respectively disposed between the seats **32**, **33** and **34**, **35**. A solenoid, not shown in Figs. 3 or 4, may be positioned around the cap **37**, and, when energized, it pulls the stem **36** upwardly to seat the elements **38** and **39** on the seats **32** and **34**. When deenergized, the valve elements seat by gravity on the opposite seats **33** and **35**.

The body **31** is formed with a series of ports, port **16** being disposed between the large seats **32** and **33**. Another port **41** is located between the seats **32** and **35**, while the fourth port **43** is located above the seat **34**. The spaces below the seat **33** and above the seat **34** are interconnected by a manifold **44**. The refrigerant connections to the various ports are designated by the same reference numerals as are used in Fig. 1. In the deenergized position of the valve **17**, compressed refrigerant flows through port **16**, past valve seat **32**, and thence through line **18** to the outside coil **19**. Expanded refrigerant leaving the inside coil **24** through line **25** flows past seat **34** and thence to the compressor **11** through the suction line **26**.

Upon energizing the solenoid, designated by the reference numeral **45** in Fig. 1, the valve elements **38** and **39** are shifted to the opposite seats **32** and **34**, which causes the compressor discharge to flow past the seat **33**, through the manifold **44**, and thence into the inside coil **24** through the line **25**. Refrigerant flowing from the out-

side coil 19 through the line 18 now passes the seat 35 for return to the compressor 11 through the line 26, thus reversing the refrigerant flow path between the two coils 19 and 24, and interchanging their functions as heat rejectors or heat absorbers. These flow paths are indicated by solid arrows for the direction making the inside coil the evaporator, and by broken line arrows for the opposite direction. It will be noted that the flow from and to the compressor is the same in both instances.

It will also be noted that the high pressure refrigerant always acts to press the valve element 38 firmly against either seat 32 or 33, but has a tendency to unseat valve element 39. For this reason, the seats 34 and 35 are of less area than the seats 32 and 33, to maintain a force differential constantly acting on element 38 to hold both valves 38 and 39 on their seats. This force is not so great, however, as to require a very strong solenoid. Another feature is that the valve may be reversed while the compressor 11 is running, and it is unnecessary to equalize the system between the high and low sides, as is done with other reversing valves of known types.

The control of the flow through the refrigerant circuit is effected through a dual thermostatic switch disposed in the room with the coil 24. This switch is shown diagrammatically, as there are a variety of such switches, applicable to the present invention, manufactured and sold by a number of organizations, and the present invention is not dependent upon the utilization of some particular manufacturer's product. The control instrumentality 51 includes a pair of switch arms 52 and 53, which, depending upon the temperature conditions in the room, will be engaged with either electrical contacts 54, 55, and 56, 57, respectively. The control is thus shown as including two single pole, double throw, thermostatically actuated switch members, but it will be understood that single pole, on-or-off switches can be used. In fact, in the present wiring arrangement, the contact 54 of switch arm 52 is not used.

Let it be assumed for purposes of explanation that the adjustments of the thermostatic control 51 are such that, at a temperature of say, 72° F., the switch arm 52 will be shifted from the solid line position, and out of contact with point 54, to the dotted line position, in engagement with the contact 55, and that it will remain in the dotted line position until the room temperature increases to say, 76° F., when it will be shifted back to the solid line position. Similarly, it may be assumed that switch arm 53 will be in the solid line position until the room temperature drops to about 66° F., when it will shift to the dotted line position to engage contact 57, and that it will remain in the dotted line position until the room temperature is raised to say, 72° F., when it will be shifted back to the solid line poistion. These values need not be adhered to exactly, in fact, most commercial thermostats have a tolerance of at least two degrees plus or minus, but the values chosen will serve as illustrations of the operation of the system.

The pivots of switch arms 52 and 53 are, or may be connected respectively to the line wires L1 and L2 through a step-down transformer 61. The solenoid 45 for valve 17 is bridged across contacts 55 and 57 by means of wires 63 and 64. Accordingly, as long as either, or both, of arms 52 and 53 are in the solid line position, solenoid 45 will be deenergized, and the flow through the valve 17 will be in the direction making coil 24 the evaporator, and thus conditioned to cool the enclosure. Under these conditions, and with the compressor 11 running, the room air will be circulated through and cooled by the coil 24, until the ambient temperature drops to about 72°, when the switch arm 52 will be shifted to engage contact 55. This will not, however, energize the solenoid 45 to reverse the refrigerant flow, as arm 53, by asumption, will not shift until the temperature drops to about 66°.

Another circuit is now established, however, to interrupt the normal functioning of the coil 24 as an evaporator, and thereby prevent excessive overcooling of the room air. The compressor discharge line 15 is provided with a branch 66 leading to the intake port 67 of a solenoid valve 68, and the outlet from the valve is coupled to a line 69 connected to the line 21 between the outside coil 19 and the strainer 22. The coil 71 of the valve 68 is connected by wires 72 and 73 to contacts 55 and 56 of the control instrument 51, and accordingly will be energized when the switch arm 52 is in the dotted line position and the arm 53 is in the solid line position. Upon energization, the valve stem 74 is elevated from its seat, thereby admitting hot compressed refrigerant gas to the line 21, which gas may then flow into the capillary 23.

The effect of this gas flow is to deprive the inside coil 24 of its normal supply of condensed refrigerant liquid, as the capillary tube 23 is notoriously inefficient as a conductor for gas, compared to its ability to transmit liquid. Hence, the cooling function of the coil 24 is substantially eliminated, and further significant artificial cooling of the room air will not take place until the switch arm 52 is released from contact 55, when the coil 71 will be deenergized, permitting the valve stem 74 to seat by gravity. It will be noted that this "off-cycle" circuit differs from a hot gas defrosting circuit, in that the hot gas is tapped into the line 21 in advance of the capillary 23, rather than at the discharge end thereof.

When the room temperature drops to a predetermined point, switch arm 53 is shifted from contact 56 to contact 57, thus opening the circuit to the coil 71, and establishing the circuit through contacts 55 and 57 to the solenoid 45 of reversing valve 17. The flow of refrigerant between the coils 19 and 24 is now reversed, and the inside coil 24 becomes the condenser, while the outside coil 19 functions as the evaporator. As previously described, when the room air is warmed to the desired temperature, the switch arm 53 returns to engage contact 56, thus placing the machine again in its "off-cycle" condition.

When the outside air temperature drops to around 40° F. or lower, and the machine is then biased to operate with the coil 19 functioning as the evaporator, there is a tendency for frost to form on the outside coil, interfering with the efficiency of operation. In order to dispose of the frost, provision is made for intermittently defrosting the coil 19, by means of a hot gas defrost circuit. The refrigerant circuit comprises the branch discharge line 66, valve 68, and lines 69 and 21, and it will be noted that with reverse cycle operation, the hot refrigerant gas is supplied directly to the coil 19, and it by-passes the coil 24 and capillary 23, in contradistinction to the condition existing when flow in the opposite direction is interrupted.

The electrical circuit for the solenoid 71 also includes a thermostatically actuated switch 81, which may be a microswitch, located out of doors and adjacent the coil 19. This switch has a pair of jointly operated arms 82, 82*a*, adapted to engage a contactor 83 when the switch is closed in response to the movement of a bimetallic thermally responsive element 84. Other types of thermostats may, of course, be used. The element 84 is adjusted to hold the arms 82, 82*a* away from the bar 83 at outdoor air temperatures above say, 40° or 45° F., and to make periodic contact at lower temperatures. When the switch is closed, a circuit is established to energize the solenoid 71 to open the valve 68 as follows: From line L2 to contact 59 and thence to pivot 85 of arm 82, contactor 83, line 87 to contact 56, line 73 to solenoid 71 and thence through line 72 to contact 55, arm 52 to line L1. The valve 68 is thereby opened to admit hot gas to the coil 19 to melt any frost and interrupt its normal function as an evaporator.

The closing of the switch 81 also establishes a circuit through a resistance heating element 89, one end of which is connected to one side of the line through a wire 91, and the other end of which is connected by a wire 86 to the pivot of switch arm 82*a*, and thence through contactor 83 to the opposite side of the line. The effect of the heat is, of course, to raise the temperature of the element 84, causing it to break the circuits to the coil 71 and the heater 89. The valve 68 thereupon closes, to shut off the hot gas supply to the heat interchanger 19, which then resumes its function as an evaporator. The dot and dash line 92 around the outside thermostat represents an enclosing casing which may contain an amount of insulating material determined by simple test from the climatic conditions existing at the place of installation, and, of course, the size or capacity of the machine.

Thus, a time factor may be established, during which the heat from the element 89 is dissipated through the insulation to the outside air and the temperature of the element 84 is again lowered to a point where it will close the switch 81, to repeat the cycle. It will be seen that, as the outdoor temperature decreases, the frequency of defrosting increases, due to the greater temperature differential between outdoor air temperature and thermostat setting temperature, with concurrent increase in the heat transfer gradient. Additional defrosting is therefore effected as the likelihood of frost formation increases.

It will be noted that this defrosting cycle enables the machine to remain in operation as a heat pump at comparatively low temperatures, when the need for interior heating has increased. It will also be seen that the controls enable the machine to operate continuously, and to change over from one function to another in response to the interior and exterior temperatures. Obviously, numerous changes, modifications and variations may be made without departing from the principles of the invention, and it is accordingly intended to encompass within its scope all such embodiments as are covered by the following claims.

I claim:

1. A reversible cycle refrigerating apparatus comprising a compressor and a motor for operating the same, a first heat interchanger adapted to be positioned outside an enclosure and a second heat interchanger adapted to be positioned inside said enclosure, refrigerant connections between the compressor and interchangers to connect the same cyclically in series, said connections including reversing valve means to deliver compressed hot refrigerant selectively to either of said interchangers, refrigerant metering means to deliver condensed refrigerant from the interchanger then functioning as a condenser to the other interchanger, thermostatic control means adapted to be positioned in the enclosure and operative to actuate the reversing valve means to constitute the inside interchanger a condenser when the temperature in the enclosure drops to a predetermined low value, a normally closed by-pass valve having an inlet connected to the compressor discharge outlet and an outlet connected between the metering means and the first interchanger, a second thermostatic control means adapted to be positioned outside the enclosure and operative to open the by-pass valve when the temperature adjacent the outside exchanger drops to a still further low value, thereby to admit hot gas to the outside interchanger, and a heater coordinated with said second thermostatic control means and energized when said second control means is actuated to open the by-pass valve to bring the temperature of said second control means above the last named further low temperature value, thereby intermittently to restore the by-pass valve to closed position.

2. A reverse cycle refrigerating apparatus comprising a compressor, condenser, refrigerant metering means and an expander connected cyclically in series to provide a closed refrigerant circuit, said condenser adapted to be positioned in an enclosure and said expander adapted to be positioned outside of said enclosure, whereby said apparatus may function as a heat pump for the enclosure, a normally closed by-pass valve connected between the compressor outlet and the expander side of the metering means, a thermostatically operated control switch positioned outside of the enclosure adjacent the expander, a heater positioned adjacent the switch, a casing for the switch and heater, said switch being adjustable to close when the outside air temperature drops to a predetermined low value and to open when the temperature in the casing is raised above such value, electrical connections to the switch and heater to supply current to the heater and to means for opening the by-pass valve when the temperature in the casing drops to said predetermined low value, whereby the heat generated in the heater will actuate the switch to open position and the heater will be deenergized, said casing providing a thermal barrier between the switch and outside air to provide a time delay period before said switch responds to said predetermined low temperature value, whereby, when said predetermined low value persists, hot refrigerant will be intermittently admitted to the expander to prevent accumulations of frost thereon.

3. A reversible cycle refrigerating apparatus comprising a motor driven compressor and a pair of heat interchangers connected cyclically in series, a reversing valve having connections to the outlet and inlet of the compressor and other connections to each of said interchangers, an operating means for said valve adapted, upon actuation, to interchange said last named connections whereby said interchangers may selectively function either as a condenser or an expander, a refrigerant metering device connecting said interchangers for directing refrigerant from the interchanger then serving as the condenser to the other interchanger, one of said interchangers adapted to be positioned in an enclosure and the other outside said enclosure, a normally closed by-pass valve interconnected between the outlet of the compressor and the outside interchanger on the metering device side thereof, and thermostatic control means for operating the reversing valve and the by-pass valve, said last named control means comprising a first thermally responsive control member inside the enclosure and a second thermally responsive control element outside the enclosure and adjacent the outside interchanger, said first thermally responsive control means having a plurality of operating positions respectively biasing the reversing valve to constitute the inside interchanger an expander and close the by-pass valve, to open the by-pass valve to starve the expander, to bias the reversing valve to constitute the outside interchanger an expander and concurrently close the by-pass valve, and to open the by-pass valve while the outside coil continues to function as an expander, said plurality of operating positions being adjustable to respond to selective different temperatures, said second thermally responsive control element having a closed operating position biasing the by-pass valve to open position and an open position biasing the by-pass valve to closed position, said element being biased to closed position at a temperature lower than those governing the movements of the first thermally responsive control means, and a heater adjacent said second element energized when said element is in closed position to raise it above said last named lower temperature, said heater being deenergized when said second element is in open position.

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