

March 15, 1960

J. R. HARNISH
HEAT PUMP SYSTEMS

2,928,255

Filed April 4, 1957

4 Sheets-Sheet 1

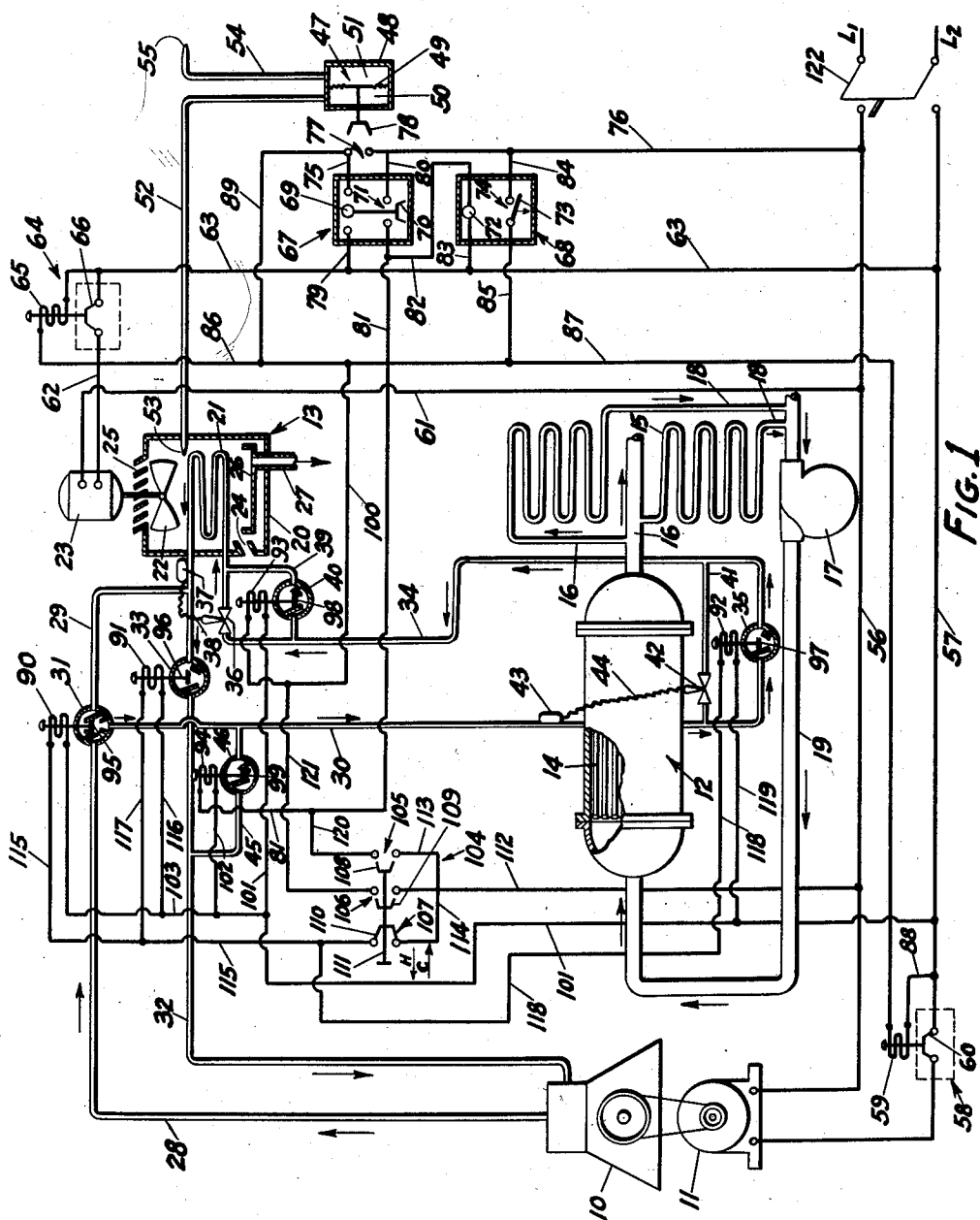


FIG. 1

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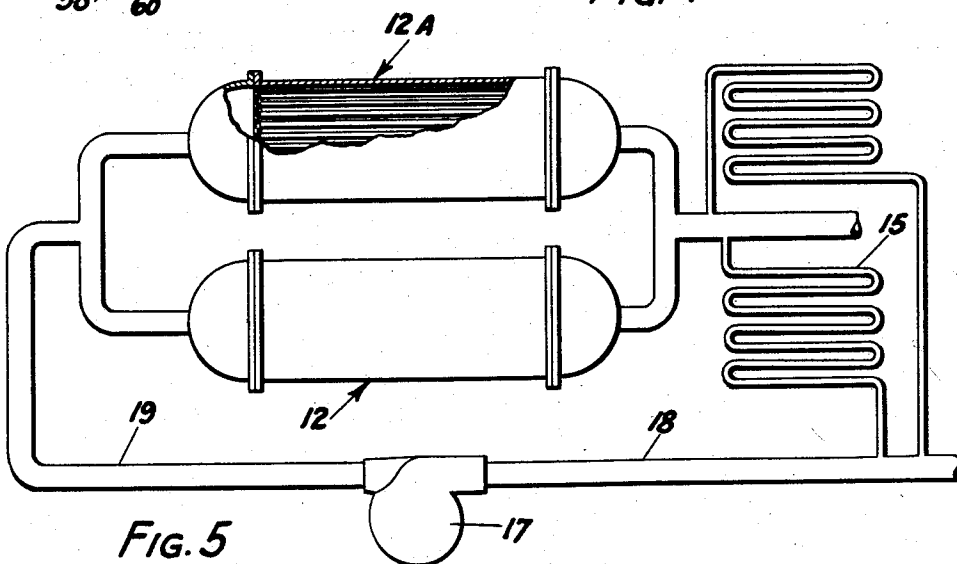
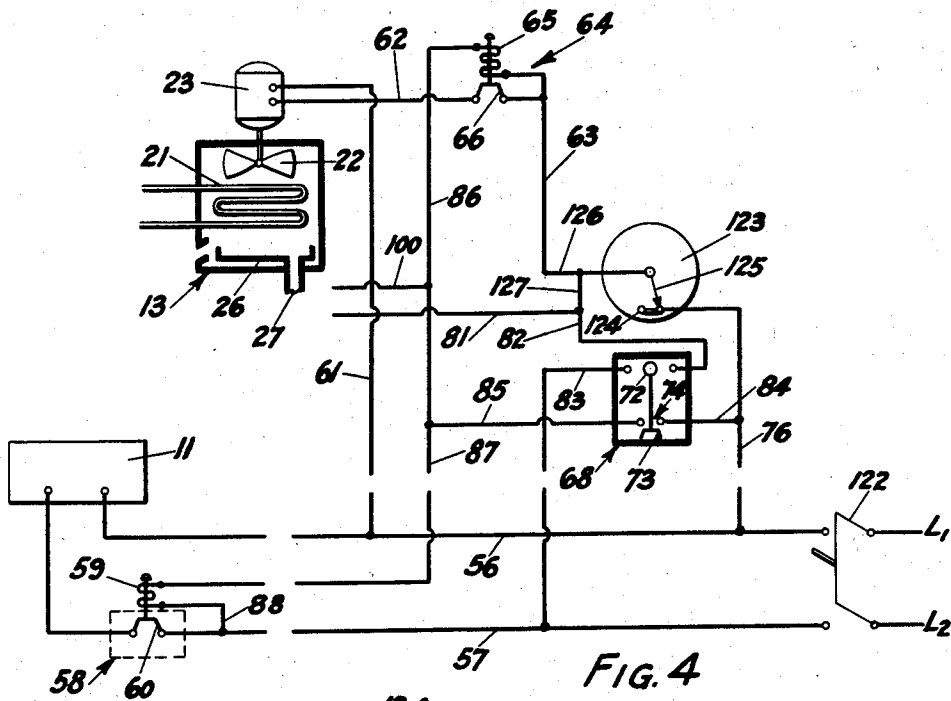
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4 Sheets-Sheet 2



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4 Sheets-Sheet 3

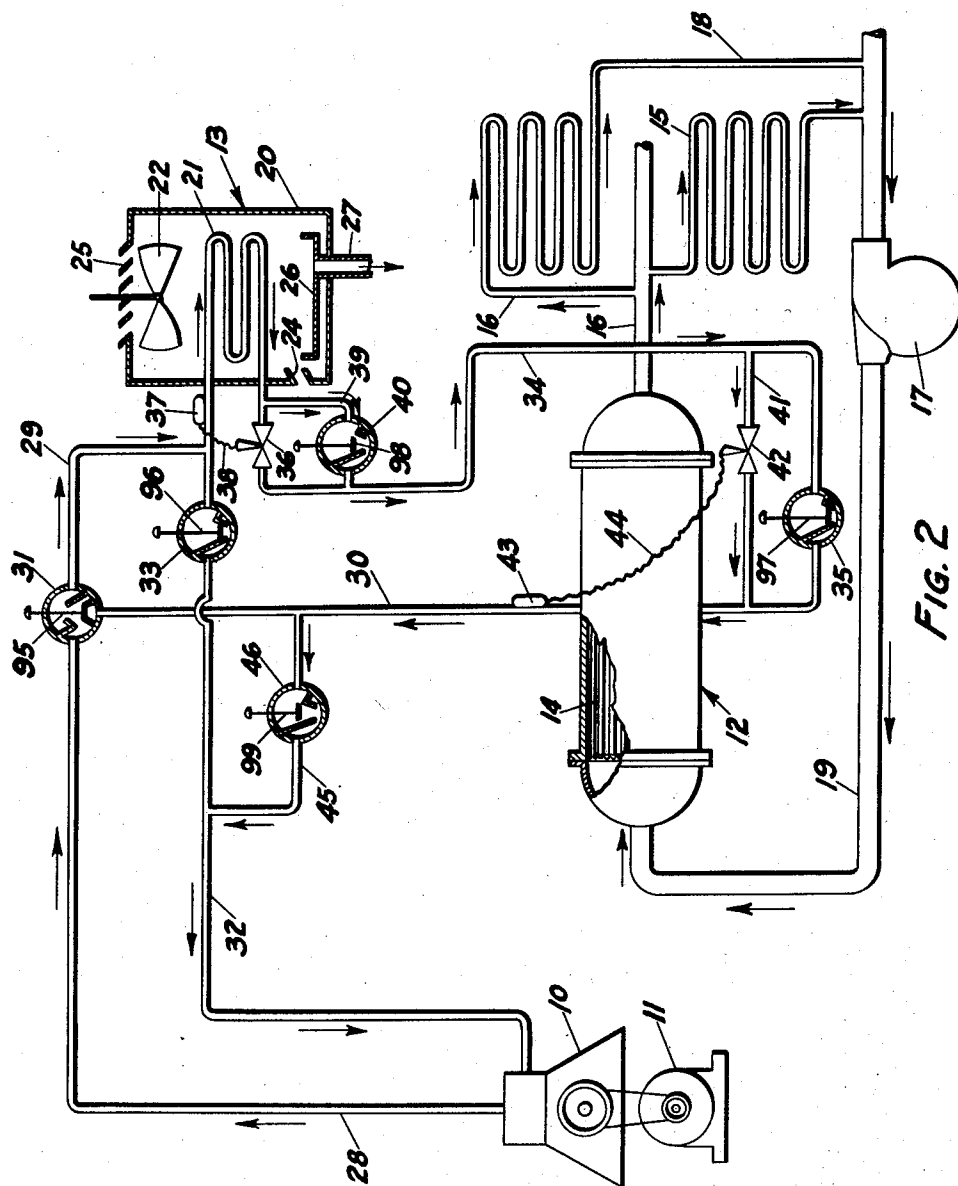


FIG. 2

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4 Sheets-Sheet 4

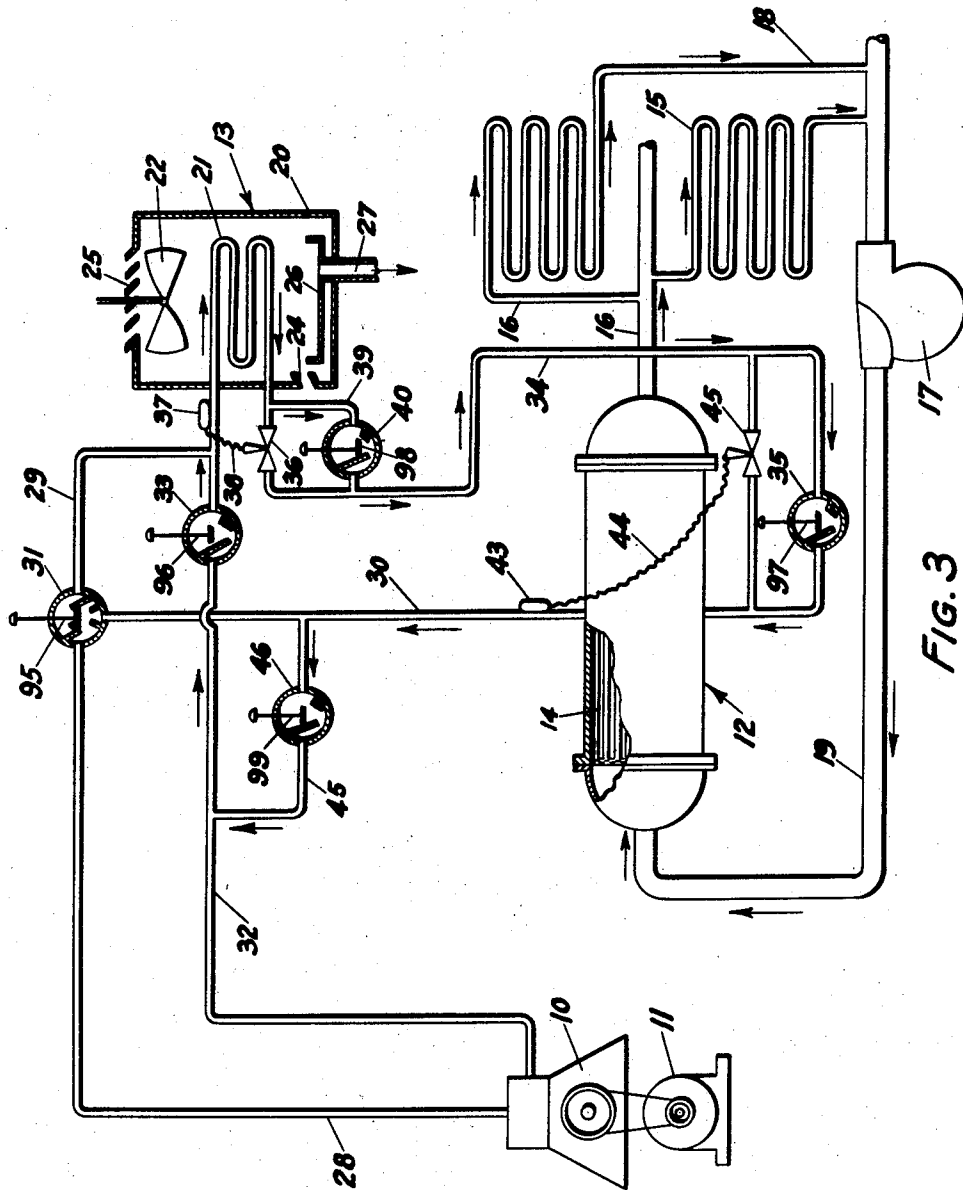


FIG. 3

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1

2,928,255

HEAT PUMP SYSTEMS

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Application April 4, 1957, Serial No. 650,679

4 Claims. (Cl. 62—81)

This invention relates to heat pumps and more particularly to defrosting arrangements therefor. As is well known, a heat pump is a reversed refrigerating apparatus wherein an outdoor heat-exchanger picks up heat from outside air, water or the ground, etc. with this heat being rejected by an indoor heat-exchanger to a fluid to be heated, which operation is the reverse of that encountered in the fluid cooling operation of the refrigerating apparatus.

In a heat pump using outside air as a heat source, with which this invention is particularly concerned, as the outside air drops in temperature, the capacity of the system falls off. Therefore, heat pumps formerly were in general use only in those areas wherein there were no sustained cold periods below approximately 30° F. However, with the continual refinements and improvements in heat pump systems, such as shown, for example, in application No. 517,971, now Patent No. 2,869,335, owned by the assignee of my invention, their use has now been extended to colder areas where formerly they were considered unsuitable for use.

With such a heat pump system utilizing outside air as a heat source there arises the problem of defrosting the outdoor heat-exchanger refrigerant coil. A temperature differential of between 10° and 25° must be maintained between the outside air and the refrigerant within the coil so that heat may flow from the outside air to the refrigerant. Under certain conditions of operation, with low temperature and high humidity conditions, a considerable frost build-up on the coil will ensue, thereby cutting down the heat transfer ability of the heat-exchanger. Means must, therefore, be provided for either periodically defrosting the coil at some predetermined timed interval, or for automatically sensing a frost build-up on the coil and initiating the defrosting mechanism when that frost build-up has reached some predetermined point.

On what is known as an air-to-air heat pump wherein outside air is the heat source and the fluid to be heated is room air, this defrosting arrangement can be effected by reversing the apparatus wherein the indoor heat-exchanger functions as an evaporator taking heat away from the room air and the outdoor heat-exchanger functions as a condenser melting any frost accumulated on the coil thereof. This procedure can be followed even though a freeze-up of the indoor heat-exchanger might occur since such a freeze-up would not be detrimental.

However, in those heat pump systems known as air-to-liquid, wherein heat picked up from outside air is transferred to a liquid such as water, for heating the same, this procedure of reversing the operation of the heat pump is not readily available. With the outdoor coil considerably frosted and therefore at a substantially constant temperature no greater than 32° F. and at a pressure substantially corresponding thereto, reversing the operation of the heat pump must, of necessity, lower the pressure within the indoor heat-exchanger to a value where its pressure and corresponding temperature will be lower than that of the outdoor coil as in normal re-

2

frigerating operations. It will be appreciated, however, that there will be a great danger of freezing the water within the indoor heat-exchanger since the sub-freezing temperatures therein will be maintained by the compressor during the entire defrost cycle. A typical liquid type indoor heat-exchanger will consist of a liquid tight shell having a tube bundle mounted therein. This danger of freezing is present even in that type of heat-exchanger wherein refrigerant is circulated within the tubes of the heat-exchanger and the water to be heated or cooled circulates over the tubes since an accumulation of ice within the shell could be detrimental. The problem, however, is considerably more aggravated in that type of heat-exchanger wherein the water circulates within the tubes and the refrigerant flows thereover. It can be readily seen that the freezing of the water within the tubes could result in rupturing the tubes with a consequent break-down of the system.

In Patent No. 2,430,938, assigned to the assignee of my invention, there is disclosed a defrosting arrangement admirably suited for heat pump operation. As shown therein, when defrosting of the outdoor heat-exchanger (evaporator) is necessary, the compressor is stopped and the outdoor heat-exchanger and indoor heat-exchanger (condenser) are placed in free communication so that the pressures therebetween may equalize. Liquid refrigerant within the outdoor heat-exchanger then flows by gravity to the indoor heat-exchanger picking up heat from a heat-exchange liquid flowing therethrough and becoming vaporized thereby. The vapor builds up in pressure within the indoor heat-exchanger to a point where it will flow to the outdoor heat-exchanger giving up its heat therein for defrosting purposes. In giving up its heat, the refrigerant vapor is condensed thereby completing the cycle.

In such an arrangement, the pressure and temperature in the indoor heat-exchanger remains at a substantially elevated level during the defrosting cycle minimizing the danger of ice formation therein.

The disclosed defrosting method, however, is not completely suitable for my purposes in that the operation is not automatic. While manual operation is feasible, it will be apparent that automatic operation is far more desirable and, in fact, necessary in large installations. In addition thereto in the disclosed defrosting method, once the defrosting is accomplished, and the system put back into normal operation, it takes a relatively long period of time for the liquid refrigerant within the indoor coil to work its way back to the outdoor coil. During such time, the entire system operates at an efficiency well below normal.

It is an object of the invention, therefore, to provide a defrosting arrangement for a heat pump including a compressor, an air-to-refrigerant outdoor heat-exchanger and a refrigerant-to-liquid indoor heat-exchanger wherein the compressor is shut down and unevaporated refrigerant is allowed to flow from the outdoor to the indoor heat-exchanger to absorb heat from the fluid therein, and evaporated refrigerant flows from the indoor to the outdoor heat-exchanger giving up its heat for defrosting the outdoor heat-exchanger, and means are provided for rendering the entire operation automatic. Another object of the invention is to provide a defrosting arrangement of the type above-mentioned wherein means are provided for quickly returning liquid refrigerant from the indoor heat-exchanger to the outdoor heat-exchanger after the termination of the defrosting operation.

Yet another object of the invention is to provide a heat pump comprising a compressor, an indoor heat-exchanger and an outdoor heat-exchanger and means for defrosting the heat pump, the defrosting means comprising means for deactuating the compressor, and means

3

for equalizing the pressure between the two heat-exchangers for liquid refrigerant to flow by gravity from the outdoor to the indoor heat-exchanger absorbing heat therein and becoming evaporated, with the evaporated refrigerant then flowing to the outdoor heat-exchanger to give up its heat and become condensed and wherein means are provided for rapidly returning liquid refrigerant from the indoor to the outdoor heat-exchanger when the defrosting cycle is completed, which means consists essentially in providing for the normally higher pressure in the indoor heat-exchanger to re-establish itself whereby said higher pressure forces all liquid refrigerant to the outdoor heat-exchanger.

In carrying out the invention, a heat pump is provided having means for defrosting the same. During the defrosting cycle, two unobstructed flow paths are provided between the indoor and outdoor heat-exchanger, allowing the pressure to equalize therein; liquid refrigerant within the outdoor heat-exchanger then flows by gravity through one of the flow paths to the indoor heat-exchanger picking up heat from the heat-exchange liquid therein and becoming vaporized; this vapor builds up in pressure sufficiently to flow through the other of the flow paths back to the outdoor heat-exchanger where it gives up its heat for defrosting the outdoor heat-exchanger and becomes condensed to complete the cycle, all as is shown in the aforesaid Patent No. 2,430,938. In addition, means are provided for rendering the entire operation automatic.

On terminating the defrost cycle, I provide means for first closing the flow path for the refrigerant vapor. In so doing, the pressure in the indoor heat-exchanger builds up to a point corresponding to its temperature, which, of course, is considerably higher than that of the outdoor heat-exchanger. By virtue of this difference in pressures, the liquid in the indoor heat-exchanger is then forced through the still open liquid flow path back to the outdoor heat-exchanger, at which time the normal heating cycle again commences, with refrigerant flow between the two heat-exchangers being at a controlled rate.

The invention consists of the novel constructions, arrangements and devices to be hereinafter described and claimed for carrying out the above-stated objects and such other objects as will appear from the following description of preferred embodiments of the invention described with reference to the accompanying drawings, in which:

Fig. 1 is a schematic representation of a heat pump embodying the novel defrosting arrangement and includes electrical controls;

Fig. 2 shows refrigerant flow paths on the cooling cycle;

Fig. 3 shows refrigerant flow paths on the defrost cycle;

Fig. 4 shows an alternate control means for initiating the defrost cycle; and

Fig. 5 shows a heat-exchange liquid circuit for a system utilizing more than one heat pump.

Turning now to the drawings, the basic components of the heat pump comprise a compressor 10 driven by an electric motor 11, an indoor heat-exchanger 12 and an outdoor heat-exchanger 13.

Indoor heat-exchanger 12 is preferably of a shell and tube type including, a tube bundle 14 therein through which the heat-exchange liquid to be either heated or cooled is circulated. Heat-exchanger 12 may be located anywhere within the building to be conditioned.

The heat-exchange liquid circuit comprises essentially a plurality of heat-exchangers 15 located in the spaces to be conditioned and connected to tube bundle 14 by way of liquid lines 16. A pump 17 has its inlet connected to the heat-exchangers 15 by liquid lines 18 and its outlet connected to tube bundle 14 of indoor heat-exchanger 12 by way of a liquid line 19.

Heat-exchanger 13 is located generally on the roof of

4

the building, or in any other area in free communication with outside air. Heat-exchanger 13 must be a sufficient height above heat-exchanger 12 so that refrigerant liquid will flow by gravity from the outdoor heat-exchanger to the indoor heat-exchanger when defrosting is desired. Heat-exchanger 13 comprises a casing 20 having therein a refrigerant coil 21 through which is circulated the refrigerant to be either evaporated or condensed, depending on whether the system is heating or cooling. Outside air is circulated over the coil by a fan 22, of any suitable type, located within the casing or adjacent thereto and driven by an electric motor 23. An air inlet opening 24 is provided in casing 20 for allowing air to be drawn over the coil 21, the air then being discharged through an outlet opening 25 provided for this purpose. A drip pan 26 provided with an outlet line 27 is provided for receiving the drip off of coil 21 and draining it away to the sewer. It will be appreciated that a forced draft system could instead be utilized wherein the fan would be located on the air entering side of the heat-exchanger.

When referring to an "indoor" heat-exchanger, I mean only that the heat-exchanger is in heat-exchange relation with the liquid to be heated or cooled, which liquid is then utilized in heat-exchangers 15 for heating or cooling the space to be conditioned. When referring to an "outdoor" heat-exchanger, I mean only that this heat-exchanger is in heat-exchange relation with outside air for dissipating heat when the system is cooling, or picking up heat when the system is heating. It will be appreciated, then, that the terms "indoor" and "outdoor" refer to function rather than location.

Suitable refrigerant flow lines are provided between compressor 10, indoor heat-exchanger 12 and outdoor heat-exchanger 13, including a hot gas refrigerant line 28 and branch lines 29 and 30 connected thereto by way of three-way valve 31. It will be appreciated that in one position of valve 31, gas refrigerant line 28 will be communicated with branch line 29, while in the other position of valve 31, gas refrigerant line 28 will be communicated with branch line 30. A suction line 32 having a valve 33 therein joins one end of coil 21 with the inlet of the compressor 10. The other end of coil 21 connects with the indoor heat-exchanger by way of a liquid line 34 having a valve 35 therein. Liquid line 34 also contains a refrigerant feeding device such as a thermal expansion valve 36 controlled by a bulb 37 connected thereto by way of a capillary 38, bulb 37 being in heat-exchange relation with suction line 32. An increase in temperature in the gas flowing through suction line 32, indicating that insufficient liquid refrigerant is being admitted to coil 21, acts through bulb 37 and capillary 38 to open thermal expansion valve 36 more fully to admit more liquid to coil 21. Conversely, on a decrease in temperature in suction line 32, thermal valve 36 is slightly closed to decrease the amount of refrigerant fluid admitted to coil 21. A bypass 39, containing a valve 40, is provided for bypassing the thermal expansion valve 36 when the system is on the cooling cycle or defrosting cycle. A bypass 41 is provided around valve 35 and has a refrigerant feeding device such as a thermal expansion valve 42 therein, controlled by a bulb 43 connected thereto by way of capillary 44; bulb 43 being in heat-exchange relation with branch line 30. A bypass line 45 controlled by a valve 46 is provided for joining branch line 30 with suction line 32.

A pressure responsive control 47 is provided for automatically initiating a defrost cycle upon a predetermined accumulation of frost on coil 21. The control 47 includes a housing 48, having a diaphragm 49 therein, dividing the housing into two chambers 50 and 51. Chamber 50 is communicated with the outdoor heat-exchanger adjacent to fan 22 by way of a line 52 terminating in a restricted orifice 53. Chamber 51 is maintained at atmospheric pressure by a line 54, terminating in a re-

5

stricted orifice 55, line 54 being so arranged that it will at all times be subject to atmospheric pressure.

The system includes an electrical control circuit comprising main lines 56 and 57 directly connected to electric motor 11. A solenoid switch 58, including a solenoid 59 and switch arm 60, is provided in line 57 for breaking the circuit to motor 11 when the defrost cycle is initiated. Fan motor 23 is connected to line 56 by way of a lead 61 and is connected to line 57 by leads 62 and 63. Lead 62 has a solenoid switch 64 therein including, a solenoid 65 and a switch arm 66. A conventional time controlled device 67 and a conventional time off delay relay 68 with an adjustable time off are provided for regulating the length of the defrost cycle. Time controlled device 67 may be of the type shown in the Paragon Electric Company bulletin No. BTS-102-1, Drawing No. C-34C, as an "Interval Timer," Model Z, Type 41, Pilot 1A, Reset 1, and includes a timer 69, controlling a switch arm 70 for closing a normally open switch 71. Time controlled device 67 is of that type wherein an electrical circuit is set up through timer 69 to close switch 71 for a predetermined time interval, as determined by the timer 69. After the predetermined time interval, the electrical circuit through the timer 69 is broken thereby, and switch 71 assumes its normally open position. Time off delay relay 68 may be of the type shown in the Allen-Bradley bulletin No. 849, page 111, style No. B, and includes a delayed action timer 72, controlling a switch arm 73 for opening or opening or closing a normally open switch 74. Time off delay relay 68 is of the type wherein an electrical circuit is set up through delayed action timer 72 to close switch 74. Delayed action timer 72 is not a self de-energizing timer as is timer 69, but is instead of the type wherein, upon de-energization thereof, switch 74 is maintained in its closed position for a set, predetermined time interval as determined by timer 72, after which time it assumes its normally open position. Timer 69 has one side connected to line 56 by leads 75 and 76 interconnected by a normally open switch 77. Switch 77 is adapted to be closed by a switch arm 78 connected to diaphragm 49. The other side of timer 69 is connected to line 57 by way of lead 79 and the aforementioned lead 63 to complete the circuit through the timer when switch 77 is closed. Switch 71 has one side thereof connected to lead 76 by a lead 80 and the other side thereof is connected to a lead 81. Delayed action timer 72 has one side thereof connected to lead 81 by a lead 82 and the other side thereof is connected to line 63 by a lead 83. Switch 73 has one side thereof connected to lead 76 by a lead 84 and the other side thereof connected to a lead 85.

Solenoid 65 has one side thereof connected to lead 85 by a lead 86. The other side of solenoid 65 is connected directly to lead 63. Solenoid 59 is connected to lead 85 by a lead 87 and to line 57 by a lead 88. A holding circuit for timer 69 is provided through a lead 89 connected to lead 86.

In order to render the operation of valves 31, 33, 35, 40 and 46 automatic, they are provided with solenoids 90, 91, 92, 93 and 94 controlling valve cores 95, 96, 97, 98 and 99 respectively.

Valves 40 and 46, which are normally closed for the heating cycle, must be open for the defrosting cycle, for reasons to be later explained. This is provided for as follows: valve 40 has one side of solenoid 93 connected to lead 86 by way of a lead 100 and the other side thereof connected to line 57 by way of a lead 101. Solenoid 94 of valve 46 has one side thereof directly connected to lead 81 and the other side connected to lead 101 by way of a lead 102 connected to a lead 103, which lead is connected to lead 101.

A cycle switch 104 is provided for controlling the operation of the heat pump for cooling or heating. Cycle switch 104 comprises switches 105, 106 and 107 adapted to be opened or closed by switch arms 108, 109 and 110

6

respectively mounted on a sliding arm 111. Switch 106 has one side thereof connected to line 56 by a lead 112. Switches 105 and 107 have one side thereof connected to line 56 by way of leads 113 and 114 connected to lead 112.

Solenoid 90 has one side connected to switch 107 by a lead 115. The other side of solenoid 90 is directly connected to lead 103. Solenoid 91 is connected across leads 103 and 115 by leads 116 and 117 respectively. Solenoid 92 has one side thereof connected to lead 115 by a lead 118 and the other side is connected to lead 101 by a lead 119. Switch 105 has the other side thereof connected to lead 81 by a lead 120. Switch 106 has the other side thereof connected to lead 100 by a lead 121.

Current is supplied to lines 56 and 57 through a master switch 122 connected to any suitable source of supply.

In operation, when cooling is desired, the operator moves sliding arm 111 to the right from its position shown in Fig. 1, thereby closing a circuit through switches 105 and 106. Master switch 122 is closed, and electric motors 11 and 23 are energized, thereby operating compressor 10 and fan 22. By virtue of switches 105 and 106 being closed, solenoids 94 and 93 of valves 46 and 40 are energized, raising valve cores 99 and 98 to their upper position, thereby allowing flow through the valves, as follows: on the closing of switch 105, a circuit is completed to one side of solenoid 94 from line 56 by way of lead 112, lead 113, switch 105, lead 120 and lead 81. The other side of solenoid 94 is connected to line 57 by lead 102, lead 103 and lead 101, thus completing the circuit.

On the closing of switch 106, a circuit is completed to one side of solenoid 93 from line 56 by way of lead 112, switch 106, lead 121 and lead 100. The other side of solenoid 93 is connected to line 57 by lead 101, thus completing the circuit.

With sliding arm 111 in its cooling position, switch 107 is open. With switch 107 open, the circuit to solenoids 90, 91 and 92 is broken and valve cores 95, 96 and 97 respectively are in their lower or de-energized position. Valve 31 then communicates lines 28 and 29 and valves 33 and 35 are closed.

As shown particularly in Fig. 2, compressed refrigerant gas then flows from the compressor 10 through line 28 and valve 31 into line 29 from whence it flows part way through line 32 into coil 21 where it gives up its heat and is condensed by the air flowing thereover under the influence of fan 22. Suitable means (not shown) may also be provided for spraying water over coil 21. The liquid refrigerant then flows through bypass line 39, open valve 40, into line 34. With valve 35 closed, the liquid flows into line 41 and through thermal valve 42, whereby its pressure and corresponding temperature is reduced. The cold liquid refrigerant then flows into heat-exchanger 12 and removes heat from the heat-exchange liquid (generally water) flowing through tube bundle 14, thereby chilling the liquid. In removing this heat, the refrigerant becomes evaporated with the refrigerant gas leaving the indoor heat-exchanger by way of line 30. With valve 46 open, the gaseous refrigerant flows through bypass 45 into line 32 and thence back to compressor 10 to complete the circuit.

When heating is desired, the operator moves sliding arm 111 to the left to the position shown in Fig. 1. With sliding arm 111 in its heating position, switches 105 and 106 are open as shown, and switch 107 is closed. The opening of switches 105 and 106 breaks the circuits to solenoids 94 and 93 respectively, allowing the valve cores 99 and 98 to drop to their lower or deenergized position, closing valves 46 and 40.

The closing of switch 107 energizes solenoids 90, 91 and 92 as follows: on the closing of switch 107, a circuit is completed to one side of solenoid 90 from line 56 by lead 112, lead 114, closed switch 107 and lead 115. The other side of solenoid 90 is connected to line 57 by lead

103 and lead 101. Since solenoid 91 is directly connected across leads 103 and 115, it also is energized on the closing of switch 107. Solenoid 92 is also energized on the closing of switch 107, since it is directly connected across lines 101 and 115.

Energization of solenoids 90, 91 and 92 actuates valve cores 95, 96 and 97 respectively to their upper position. This has the effect of opening valves 33 and 35. Insofar as valve 31 is concerned, with valve core 95 in its upper position, this communicates hot gas refrigerant line 23 with branch line 30.

Hot compressed refrigerant gas then exits compressor 10 by way of line 28 and is directed by valve 31 into line 30, whence it flows into the indoor heat-exchanger 12, giving up its heat to the water or heat-exchange fluid flowing within the tube bundle 14 and becoming condensed thereby. Liquid refrigerant then exits heat-exchanger 12 by way of line 34 and flows through open valve 35. Since valve 40 is closed, the refrigerant fluid flows through thermal valve 36 where its pressure and corresponding temperature are reduced and then into coil 21 where it picks up heat from air flowing thereover under the influence of fan 22, becoming vaporized thereby. Refrigerant vapor exits coil 21 by way of line 32 through now open valve 33 and back to the inlet of compressor 10 to complete the heating cycle.

Upon a build up of frost on coil 21 sufficient to impede the flow of air through inlet opening 24 and over the coil, fan 22 pulls a partial vacuum within heat-exchanger casing 20. The less than atmospheric pressure existing within casing 20 is communicated to chamber 50 by line 52. Since chamber 51 is always at atmospheric pressure, as pointed out above, diaphragm 49 is forced to the left and switch arm 78 closes normally open switch 77. Upon the closing of switch 77, timer 69 is energized as follows: current flows from line 56 through lead 76, closed switch 77 and lead 75 to one side of the timer and thence through leads 79 and 63 back to line 57. On energization of timer 69, switch arm 70 is actuated to its upper position closing switch 71. Timer 69 then maintains switch arm 70 in its upper position for the set time interval.

With switch 71 closed, a circuit is completed through delayed action timer 72 as follows: current flows from line 56 through lead 76, lead 80, closed switch 71, leads 81 and 82 to one side of timer 72 and thence through leads 83 and 63 and back to line 57. On the energization of timer 72, switch arm 73 is actuated to its upper position, closing switch 74. As was pointed out above, delayed action timer 72 is so designed that it holds switch arm 73 in its upper position for a set time interval after the timer is de-energized. The closing of switch 74 also has the effect of breaking the circuit to compressor motor 11, stopping the operation of compressor 10 as follows: solenoid 59 is energized by current flowing from line 56 through lead 76, lead 84, closed switch 74, lead 85, lead 87, through solenoid 59 and lead 88 back to line 57. Energizing solenoid 59 actuates switch arm 60 to its upper position, breaking the circuit to motor 11, as aforementioned.

With switch 74 closed, solenoid 65 is energized to actuate switch arm 66 to its upper position as follows: current flows from line 56 through lead 76, lead 84, closed switch 74, lead 85, lead 86, thence through solenoid coil 65 and lead 63 back to line 57. With solenoid 65 energized, switch arm 66 is raised to its upper position breaking the circuit through line 62 to motor 23, thus stopping the operation of fan 22.

With fan 22 no longer operating, atmospheric pressure quickly re-establishes itself within casing 20. This atmospheric pressure is then communicated to chamber 50 via line 52 and the diaphragm then moves to the right to its normal position, opening switch 77. Timer 69 remains energized, however, by current flow from line 56 through lead 76, lead 84, closed switch 74, lead 85, lead 86, lead 89 and lead 75 to one side of the timer. Since

the other side of timer 69 remains connected to line 57 by way of leads 79 and 63, the timer remains energized for its set interval so long as switch 74 remains closed.

With switch 71 closed, solenoid 94 of valve 46 is energized as follows: current flows from line 56 through lead 76, lead 80, closed switch 71, lead 81, through solenoid 94 and thence through leads 102, 103 and 101 back to line 57 to complete the circuit. On the energization of solenoid 94, valve core 99 is actuated to its upper position, allowing flow through valve 46.

The closing of switch 74 has the effect of energizing solenoid 93 of valve 40 as follows: current flows from line 56 through lead 76, lead 84, closed switch 74, lead 85, lead 86, lead 100, through solenoid 93, thence back to line 57 by way of lead 101, thus completing the circuit. With solenoid 93 energized, valve core 98 is actuated to its upper position, allowing flow through valve 40.

As shown particularly in Fig. 3, unevaporated liquid refrigerant within coil 21, including any refrigerant within line 34 en route to coil 21, then flows by gravity back through line 39, now open valve 40, into line 34 and thence through valve 35, which is normally open during the heating cycle, into heat-exchanger 12 wherein it picks up heat from water flowing within tube bundle 14, becoming vaporized thereby. As was pointed out above, valve 46 is open allowing free communication between the two heat-exchangers, equalizing the pressures therein and allowing the gravity flow. The vaporized refrigerant within the indoor heat-exchanger builds up sufficient pressure to flow through line 30, bypass 45 and open valve 46 into line 32, thence through open valve 33 into coil 21. The vaporized refrigerant gives up its heat in coil 21, defrosting the ice formed thereon and becoming condensed thereby with the liquid refrigerant again flowing by gravity back to indoor coil 21. Water dripping off coil 21 drops into the pan 26 provided for this purpose whence it drains away by way of conduit 27 into the sewer. Heaters (not shown) may be added to the pan to melt any frost dropping from the coil to keep the water fluid.

Upon the completion of the predetermined time cycle as determined by timer 69, time controlled device 67 is de-energized allowing switch arm 70 to drop to its lower position, opening switch 71. Opening switch 71 breaks the circuit through solenoid 94, de-energizing the same, allowing valve core 99 to drop to its lower position, closing flow through valve 46. Breaking the circuit through switch 71 de-energizes timer 72. However, since delayed action timer 72 is set to maintain switch 74 closed a predetermined time interval after the de-energization thereof, solenoid 93 remains energized, maintaining valve core 98 in its upper position and valve 40 open.

With valve 46 closed, the only communication between the heat-exchangers is through line 34. Line 34, however, is full of refrigerant liquid and, therefore does not provide that free communication necessary to allow the pressure to remain equalized within the indoor and outdoor heat-exchangers. The pressure within the respective heat-exchangers then corresponds to their temperatures. Since the temperature within indoor heat-exchanger 12 is at a higher temperature than in outdoor heat-exchanger 13, the pressure therein is higher, forcing all the liquid within the indoor heat-exchanger 12 through line 34 and still open valve 40 into coil 21. After the predetermined time interval elapses, delayed action timer 72 allows switch 74 to assume its open position. Opening of switch 74 breaks the circuit through solenoid coil 93, de-energizing the coil, allowing valve core 98 to drop to its lower position, closing valve 40. The circuits through solenoids 59 and 65 are also broken, allowing switch arms 60 and 66 to drop to their lower positions closing switches 58 and 64 respectively. With switches 58 and 64 closed, motors 11 and 23 are again energized operating the compressor 11 and fan 22, and the system again operates on its normal heating cycle.

With the system set to defrost whenever there is a frost build up on coil 21 sufficient to impede the flow of air thereover, it will be appreciated that the system could be defrosting any time during the day. It will be apparent, of course, that the heat for defrosting the coil comes from the heat-exchange liquid flowing through tube bundle 14, which liquid is then utilized to heat the various rooms. Since the defrost cycle could occur during the working day and since this would have the effect of depriving the rooms of needed heat, generally the above control method is not utilized except where some additional source of heat is available for defrosting purposes.

A heat pump system wherein the above control method could be utilized to advantage is shown diagrammatically in Fig. 5. The system comprises essentially at least two separate heat pumps having indoor heat-exchangers 12 and 12A with a common water circuit and wherein the water flow through the heat-exchangers is in parallel. It is apparent that the water flow through the heat-exchangers could be a series flow. The two systems are so interlocked that only one can defrost during any period of time whereby the other would then provide the heat necessary for defrosting and also would maintain the water temperatures at some reasonable point.

Where such a heat pump system is not in use, or where an additional source of heat for defrosting is not available, then I provide the control method as shown in Fig. 4. This consists essentially of a timer control set to defrost periodically some time during the night hours so that even though the water becomes slightly cold, there may be no occupants in the building to become affected thereby.

A timer device 123 is provided replacing time controlled device 67 and also, of course, the diaphragm controlled switch arm 78. Timer device 123 essentially comprises a clock of whatever time period is desired, having for example an electrical conducting strip 124 thereon of sufficient length to provide the necessary time for defrosting. Strip 124 is placed on the clock in such a manner that the defrost cycle will begin say at the hour of midnight, or any suitable hour or hours during the night. Strip 124 is connected to lead 76. A single hour hand 125 is provided, which is also an electrical conductor and has its one terminal connected to line 63 by a lead 126. A lead 127 connects lead 82 of time-off delay relay 68 with lead 126. It will be seen that lead 81 is now connected to lead 127.

In operation, when hand 125 in its passage around the clock first contacts strip 124, an electrical circuit is set up through timer device 123 by way of lead 76, strip 124, hand 125, lead 126 and lead 63. This then energizes delayed action timer 72 by current flowing from line 56 through lead 76, strip 124, hand 125, lead 126, lead 127 and lead 82 to one side of the timer 72. The other side of the timer 72 is connected to line 57 by way of leads 83 and 63. Thenceforth the circuits parallel those of Fig. 1. Timer 123 remains energized so long as hand 125 moves on strip 124. When hand 125 moves off strip 124, the circuit through the timer device is broken, de-energizing coil 94 of valve 46, as aforementioned. After the predetermined set interval, delayed action timer 72 is de-energized allowing switch arm 73 to break the circuit through switch 74, all as set out above.

It will be appreciated that the most desirable way of effecting drainage of refrigerant liquid from the outdoor to the indoor heat-exchanger and return of refrigerant gas from the indoor to the outdoor heat-exchanger will be through two separate flow paths. However, I wish it to be understood that I contemplate that one flow path may be utilized provided it is of sufficient size to carry both the liquid and gaseous flow.

It will be seen that I have provided a defrosting arrangement for a heat pump of utmost simplicity characterized by its automatic operation and admirably suited for carrying out its intended function. The possibility

of ice forming in the indoor coil with all the consequent dangers attached thereto is greatly minimized. No miscellaneous safety controls are, therefore, required to protect the compressor and prevent freezing in the indoor heat-exchanger under normal operation. It will also be apparent that I have provided in a most expeditious manner for liquid refrigerant return from the indoor to the outdoor heat-exchanger, after the termination of the defrost cycle.

It will be further seen that I have provided an apparatus well suited in operation and function for carrying out the stated objects.

I wish it to be understood that my invention is not to be limited to the specific constructions and arrangements shown and described, except only insofar as the claims may be so limited, as it will be apparent to those skilled in the art that changes may be made without departing from the principles of the invention.

What is claimed is:

1. In a heat pump including a refrigerant compressor, an indoor heat-exchanger and an outdoor heat-exchanger, the combination of means for defrosting said outdoor heat-exchanger comprising means for staying the operation of said compressor, means establishing flow paths between said heat-exchangers for liquid refrigerant to flow from said outdoor to said indoor heat-exchanger and evaporated refrigerant to flow from said indoor to said outdoor heat-exchanger; means for actuating said defrosting means; and means for de-actuating said defrosting means comprising means for first closing the flow path for evaporated refrigerant, and for then closing the flow path for liquid refrigerant and starting said compressor.

2. In a heat pump including an indoor heat-exchanger and an outdoor heat-exchanger, the combination of means for defrosting said outdoor heat-exchanger comprising means establishing flow paths between said heat-exchangers for liquid refrigerant to flow from said outdoor to said indoor heat-exchanger and evaporated refrigerant to flow from said indoor to said outdoor heat-exchanger; means for actuating said defrosting means; and means for deactuating said defrosting means comprising means for sequentially closing first said path for the evaporated refrigerant and then, after a predetermined time interval, said path for said liquid refrigerant.

3. In a heat pump comprising a compressor, an indoor heat-exchanger functioning as a refrigerant condenser, an outdoor heat-exchanger functioning as a refrigerant evaporator, said compressor and heat-exchangers being connected in a closed refrigerant circuit, means for directing refrigerant from said compressor through said circuit first through said indoor and thence through said outdoor heat-exchanger, and means for controlling the flow rate of the refrigerant en route from said indoor to said outdoor heat-exchanger, the combination of defrosting means for said heat pump comprising means for deactivating said compressor, means for bypassing said flow controlling means for liquid refrigerant to flow through said circuit from said outdoor to said indoor heat-exchanger, and means defining a flow path for evaporated refrigerant to flow from said indoor to said outdoor heat-exchanger; means for actuating said defrosting means; and means for deactuating said defrosting means comprising means for first closing said flow path for evaporated refrigerant whereby evaporating refrigerant will build up to a pressure within said indoor heat-exchanger sufficient to force said liquid refrigerant through said circuit and bypass means to said outdoor heat-exchanger, and means for then closing said bypass, and for reactivating said compressor.

4. A defrosting method for a heat pump having a compressor, an indoor heat-exchanger, and an outdoor heat-exchanger comprising the steps of deactuating the compressor, providing direct communication between said heat-exchangers for equalizing the pressures therebe-

tween, flowing liquid refrigerant from said outdoor to said indoor heat-exchanger, passing the liquid refrigerant within the indoor heat-exchanger in heat-exchange relation with a heat-exchange liquid therein to absorb heat therefrom and become vaporized, flowing the vaporized refrigerant back to the outdoor heat-exchanger to give up its heat therein for defrosting purposes, and terminating the defrosting operation by partially closing communication between the two heat-exchangers, whereby a normally higher pressure in the indoor heat-exchanger will reestablish itself, said higher pressure then forcing liquid refrigerant from the indoor back to the outdoor heat-exchanger, and reactuating said compressor.

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10

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 2,928,255

March 15, 1960

James R. Harnish

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 5, lines 29 and 30, after "arm 73 for" strike out "opening or opening or".

Signed and sealed this 23rd day of August 1960.

(SEAL)

Attest:

KARL H. AXLINE
Attesting Officer

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Commissioner of Patents