

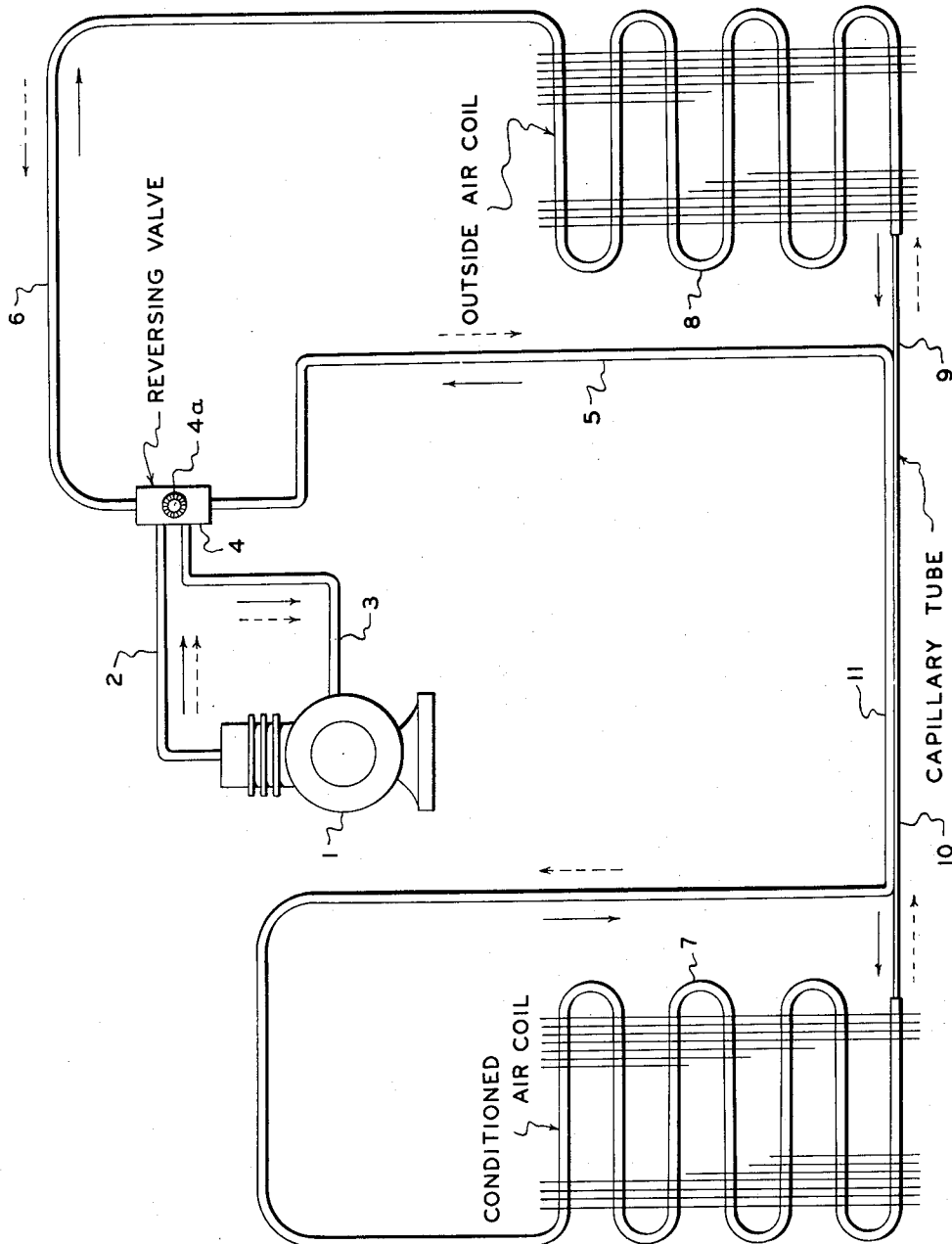
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REFRIGERATION SYSTEM FOR AIR CONDITIONING APPARATUS

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REFRIGERATION SYSTEM FOR AIR CONDITIONING APPARATUS

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My invention relates to air conditioning apparatus and more particularly to reversible cycle refrigeration systems for use in such apparatus.

Reversible cycle refrigeration systems may be included in air conditioners so that the air in the enclosure to be conditioned may be either heated or cooled for comfort. During the cooling operation the indoor coil or heat exchanger acts as an evaporator and the outdoor coil or heat exchanger acts as a condenser. Conversely during the heating operation the indoor coil acts as a condenser and the outdoor coil as an evaporator. This change in function is, of course, accomplished by reversing the direction of refrigerant flow through the system.

A problem is, however, presented by the switchover of the system from the one operation to the other. During the summer cooling operation, relatively warm room air passes over the coil acting as the evaporator and as a result it operates at a relatively high pressure and temperature. However, during the winter heating operation the coil acting as the evaporator is exposed to the cold outside air; and therefore, the evaporator pressure and temperature are relatively low. As is well known in the art, the lower the evaporator pressure, that is the compressor suction pressure, the lower is the compressor pumping capacity and flow rate through the system. But the ideal flow rate for both the heating and the cooling operation is one where the rate at which a full evaporator boils off, i. e. evaporates, refrigerant just equals the pumping rate of the compressor. If the flow rate is less than ideal, there will be superheating in the evaporator and similarly if the flow rate is greater than ideal, liquid refrigerant will flood through the evaporator and into the compressor. Flooding through of the evaporator is, of course, undesirable in that more work is done in the compressor without getting any additional conditioning effect or work out of the system.

Normally the system is designed with a particular restriction between the two coils so that the ideal flow rate is obtained for the cooling operation. But due to the changed conditions imposed upon the system and the resultant change in coil temperatures and pressures, the ideal flow rate will not ordinarily occur during the heating operation with the system so designed for the cooling operation. The restriction which is the optimum for the cooling operation is not normally the correct amount to obtain the most efficient evaporator functioning during the heating operation.

With the evaporator temperature and pressure being lower during the heating operation so that the compressor pumping rate is inherently decreased, additional restriction must be added between the two coils in order to obtain a sufficiently low flow rate that flood through does not occur. There are two principal reasons why flood through will occur during the heating operation if some additional restriction is not added. The first of these is that the temperature and pressure differential between the two coils is ordinarily increased over that which normally exists during the cooling operation. As a

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result, if a fixed restriction or expansion means is utilized between the two coils, the flow rate through the restriction would be greater than desirable. Secondly, it has been found that when a larger outdoor than indoor coil is used, as is normally done to obtain efficient operation, considerably more subcooling of the condensed refrigerant occurs during the heating operation, when the indoor coil is acting as the condenser, than during the cooling operation, when the outdoor coil is acting as the condenser. This again causes an excessive flow rate since with a fixed expansion means, and particularly with a capillary expansion tube, the greater is the subcooling of the refrigerant entering the expansion means, the greater is the flow of the refrigerant therethrough. For example, with a capillary tube the flow is greater because the refrigerant progresses further down the tube before any of it flashes into gas and impedes flow.

Thus if flood through is to be avoided, it is desirable that the expansion means between the two coils offer greater restriction during the heating cycle than during the cooling cycle. Although different expansion means can, of course, be employed on refrigeration systems, capillary tubes are generally used whenever possible. These tubes are quite inexpensive compared to expansion valves, and due to their extreme simplicity and total lack of moving parts are extremely satisfactory in operation. But since these tubes are of a fixed resistance to flow depending upon their length and cross-sectional area, they have not been readily useable with these reversible cycle systems wherein it is necessary or desirable to pass a different rate of refrigerant flow through the system in its heating operation than in its cooling operation. Due to their fixed resistance and for the reasons set forth above they will, if connected in the ordinary manner between the indoor and the outdoor coil, not pass the proper amount of refrigerant in both operations. If the capillary tube is designed for correct operation during the cooling cycle, an inefficient operation will result during the heating cycle. Of if the capillary tube should be designed for an efficient heating operation, an inefficient cooling operation will be caused. Thus in spite of their many advantages capillary tubes have not proven wholly satisfactory in refrigeration systems designed for both heating and cooling operations, as are used in many air conditioners.

Accordingly, it is a primary object of my invention to provide a new and improved reversible cycle refrigeration system utilizing capillary tube expansion means, in which an efficient refrigerant flow rate is effected during the heating cycle as well as during the cooling cycle.

It is another object of my invention to provide a new and improved reversible cycle refrigeration system using capillary tube expansion means, in which the capillary tube expansion means, in effect, offer more restriction to refrigerant flow during the heating cycle than during the cooling cycle.

In carrying out my invention in one preferred form thereof, I provide a reversible cycle refrigeration system adapted for incorporation in an air conditioner for either heating or cooling air for comfort. This system includes a compressor and indoor and outdoor heat exchangers or coils. A capillary tube is connected between the coils and serves to expand the refrigerant of the system from condensing pressure to evaporating pressure during both the heating and the cooling operations or cycles. Further included in the system are means for selectively connecting the compressor discharge and suction to the indoor and outdoor coils respectively during the heating cycle and to the outdoor and indoor coils respectively during the cooling cycle. These means comprise first and second conduits connected respectively to the indoor and outdoor coils and a reversing valve connected to the conduits and

to the compressor suction and discharge. The first conduit is arranged in heat transfer relation with at least a portion of the capillary tube, and thus according to my invention serves to heat the tube during the heating cycle and cool it during the cooling cycle. During the heating cycle the first conduit is carrying the hot discharge refrigerant from the compressor so that it gives off heat to the capillary tube, whereas during the cooling cycle the first conduit is carrying cool suction refrigerant toward the compressor so that it picks up heat from the capillary tube. As a result of this heat transfer the formation of gaseous refrigerant in the capillary tube is retarded during the cooling cycle and quickened during the heating cycle. This causes the capillary tube to be less effective to pass refrigerant during the heating cycle than during the cooling cycle and thereby effects a lower refrigerant flow rate throughout the system. With this change in the refrigerant flow rate automatically so accomplished my new and improved system may operate with good efficiency during both cycles, heating and cooling.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims. My invention itself, however, both as to its organization and method of operation may be best understood by reference to the following description taken in conjunction with the accompanying drawing, the single figure of which is a diagrammatic view of a reversible cycle refrigerating system embodying my invention.

Referring now to the diagram I have illustrated therein a refrigerating system including a motor compressor 1 having a discharge line 2 and a suction line 3. The discharge and suction lines are both connected to a reversing valve 4. Also connected to the reversing valve 4 are a pair of conduits 5 and 6 which lead respectively to indoor and outdoor heat exchangers or coils 7 and 8. The indoor coil 7 is arranged for heating or cooling the air in the enclosure to be conditioned, and the outdoor coil 8 is arranged for either rejecting heat to or picking it up from the outside atmosphere.

The reversing valve 4 which is manually controlled by means of a knob 4a is operative to selectively connect the discharge and suction of the compressor 1 to conduits 5 and 6 and thus to the inside and outside coils 7 and 8 respectively. Or it may be operated to reverse that connection and connect the discharge line 2 to the outside heat exchanger 8 and the suction line 3 to the inside or conditioned air coil 7. More specifically, if it is desired to set the system for a heating cycle, the compressor discharge is connected to the inside coil 7 through the conduit 5 and the suction is connected to the outside coil 8 through the conduit 6; whereas if it is desired to initiate a cooling cycle, the discharge is connected to the outside coil 8 through the conduit 6 and the suction is connected to the conditioned air coil 7 through the conduit 5. My invention is, however, not limited to a system in which the reversing valve is manually actuated for I contemplate that my invention may be used in systems wherein the reversing valve is automatically actuated from one position or cycle to the other. For example the valve could be electrically actuated in response to a thermostat sensitive to room temperature.

Further included in my preferred system for the purpose of expanding the refrigerant from condensing pressure to evaporating pressure is a capillary tube 9. In accordance with my invention this tube is so connected and arranged that an efficient flow rate is obtained in the system both during the heating cycle and during the cooling cycle. More specifically, this capillary tube is so connected and arranged that it offers more restriction to the flow of refrigerant during the heating cycle than during the cooling cycle whereby a lesser amount of refrigerant flows during the heating cycle.

As explained hereinbefore it is desirable that less refrigerant flow within the system during the winter heating cycle than during the summer cooling cycle in order that

the system may operate efficiently during both cycles. If the inside coil is to be run most efficiently during the cooling cycle which means running the coil full, the outside coil must be run at some lesser amount during the heating cycle if flood through is to be avoided. By running the inside coil full during the cooling cycle I, of course, mean supplying the inside coil with the particular amount of refrigerant which will result in all the refrigerant being boiled off but not superheated by the time it leaves the evaporator. But unless some lesser amount of refrigerant is supplied to the outdoor coil during the heating cycle, it will not be all evaporated and thus flood through of some liquid refrigerant will result. In other words if the coil acting as the evaporator is to be supplied with the proper amount of refrigerant for maximum system performance during both the heating and the cooling cycles some means must be provided for causing a lesser rate of flow during the heating cycle than the cooling cycle.

As mentioned above, it is through my novel arrangement of the capillary tube 9 that I accomplish this result. In other words, it is through the arrangement of the capillary tube 9 that I cause the refrigerant flow during the summer cooling cycle to be such that the inside coil 7, then acting as an evaporator, is run full and also cause a lower rate of flow to occur during the winter heating cycle so that the outside air coil 8, then acting as an evaporator, is also run substantially full but not flooded through. In my novel arrangement the capillary tube 9 is connected between the ends of the coil 7 and 8 remote from the reversing valve 4; and serves as a means for expanding the refrigerant as it flows from one coil to the other no matter in which direction the flow occurs. But in order that it be less effective to pass gas during the heating cycle than during the cooling cycle the capillary tube 9 is, by my invention, positioned in heat exchange relation with the conduit 5 connecting reversing valve 4 to inside coil 7. Specifically in my preferred embodiment the center portion 10 of the capillary tube is positioned in intimate heat exchange relation with a portion 11 of conduit 5 intermediate the ends thereof. This intimate heat exchange relation may be accomplished by any suitable means as, for example, by soldering the portion 10 of the capillary tube to the portion 11 of the conduit. As will become more apparent hereinafter the length of the portions of the conduit and capillary tube placed in heat exchange relation will vary somewhat depending upon the desired capacity of the system in which they are incorporated.

The manner in which my novel capillary tube arrangement operates to cause a lesser flow during the heating cycle than during the cooling cycle may be best understood by reference to the arrows shown in the diagram, wherein the refrigerant flow during the cooling cycle is indicated by solid arrows and the flow during the heating cycle by dotted arrows. As there shown, during the cooling cycle the discharge line 2 of the condenser is connected by the reversing valve 4 to the conduit 6 leading to the outside air coil 8 and the suction line 3 of the compressor is connected to the line 5 leading from the indoor coil 7. With these connections so made the hot gaseous refrigerant discharged from the compressor 1 flows through the conduit 6 to the outside air coil 8 wherein it is condensed or liquefied. The liquid refrigerant then enters the capillary tube 9 and passes there-through, being expanded and greatly reduced in pressure in the process. The cold expanded refrigerant then enters the inside coil 7 wherein it is boiled off or evaporated by the heat absorbed from the room air. In other words the cold, low pressure refrigerant is vaporized in coil 7 by the heat absorbed from the room air. This vaporized refrigerant, which is still relatively cool, is returned through the conduit 5 to the suction of the compressor.

The cool vaporized refrigerant flowing through the conduit 5 has a temperature substantially lower than the

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temperature of the expanding refrigerant flowing in the portion 10 of the capillary tube. As a result the vaporized suction refrigerant passing through the heat exchanger formed by the portions 10 and 11 of the capillary tube and the conduit 5 extracts heat from the expanding refrigerant flowing in the capillary tube.

Through this extraction of heat from the refrigerant in the capillary tube the efficiency of the system as a whole is increased, because the heat extracted from the refrigerant on the capillary tube increases by like amount the capacity of the refrigerant to absorb heat in the inside coil 7, acting as an evaporator. Moreover, the heat exchange also has the result of increasing the flow through the system over what it would be if no such heat exchange were present. Since the heat exchange results in lower temperatures of the refrigerant flowing in a capillary, the refrigerant is retarded from assuming a gaseous or vaporous form in capillary. The lower the temperature of the refrigerant, the lower its pressure must be before it can assume a gaseous form and hence the less is the gas formed within the capillary. As is well known in the art, the more gas present within a capillary, the more is the refrigerant flow therethrough retarded. Thus with less gas formed as result of the heat exchange the more refrigerant can flow through the tube. In fact, taking advantage of this effect my new and improved system is designed to run the evaporator substantially full of liquid refrigerant under normal operating conditions of the cooling cycle, thereby to obtain maximum system performance.

However, as a result of my invention a much lesser refrigerant flow rate is automatically obtained when my new and improved system is changed over to the heating cycle. By operating the reversing valve 4 to its heating cycle position the conduit 5 is connected to the discharge line 2 of the compressor and the conduit 6 is connected to the suction line 3 of the compressor. As a result the hot discharge refrigerant of the compressor is fed to the inside coil 7. The refrigerant after being liquefied in the coil 7 flows through the capillary tube 9 wherein it is expanded, i. e. greatly reduced in temperature and pressure. The expanded refrigerant then flows through the outside coil 8 picking up heat from the outside atmosphere, and finally returns to the compressor through the conduit 6. Thus during this heating cycle the inside coil 7 acts as a condenser rejecting heat and the outside coil acts as an evaporator picking up heat.

As mentioned above however the coil 8 operates at a lower pressure and temperature during this winter heating operation than the coil 7 does during the summer cooling operation due to the colder air surrounding the coil 8, and therefore a lower rate of refrigerant flow must be effected if flood through of coil 8 is to be avoided. In my novel system such a lower flow rate is automatically obtained in the heating operation by means of the heat interchange between the portion 10 of the capillary tube and the portion 11 of the conduit 5. Since the conduit 5 during the heating operation is carrying hot refrigerant rather than cool refrigerant it rejects heat to the portion 10 of the capillary tube rather than absorbing heat therefrom. In other words due to the reversal of the flow through the system the refrigerant flowing through the capillary is warmed because of the heat exchange rather than being cooled. Thus instead of the refrigerant in the capillary being retarded from flashing into gas it is caused to assume a gaseous form more quickly. The heat added to the refrigerant in the capillary by means of the heat exchange raises its temperature and thereby raises the pressure at which it will change into gaseous form. As a result the formation of gas within the capillary is considerably quickened.

With more gas formed therein the capillary is much less effective to pass refrigerant or in other words it offers a much greater restriction to flow than during the cool-

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ing cycle. With the capillary less effective to pass refrigerant the flow rate through the entire system is thereby decreased. In fact in my preferred system the flow rate during the heating cycle is decreased by means of this heat exchange to a point wherein the outside coil 8 acting as an evaporator is run substantially full but not flooded through under normal operating conditions. In other words as a result of this heat exchange a lower flow rate is effected within the system to allow substantially all the refrigerant entering the coil 8 to be evaporated but not superheated by the time it leaves the coil. This of course provides for good efficiency during the heating cycle. Thus as a result of my invention a refrigeration system is provided utilizing capillary tube expansion means, which not only operates efficiently during the cooling cycle but also has a lower refrigerant flow rate during the heating cycle so that it operates efficiently then too.

The length of the capillary tube 10 and the length of its heat interchange with the conduit 5 of course vary with the size of the system in which my invention is incorporated. By way of example I have found that in a system using dichlorodifluoromethane as a refrigerant and primarily designed to have a capacity of 7500 B. t. u. per hour when acting as an air-cooled room cooler, efficient operation is obtained during both the cooling and heating cycles by providing a capillary tube 49 inches long and having a bore of .075 inch, and placing this tube in heat exchange relation for 22 inches with the conduit leading to the inside coil. With such a length of heat exchange, a $\frac{3}{4}$ horsepower motor compressor and suitably sized inside and outside coils, 155 pounds per hour of refrigerant at 39 p. s. i. g. and 42 degrees F. evaporator pressure and temperature respectively are circulated during the cooling operation and 120 pounds per hour at 29 p. s. i. g. and 30 degrees F. are circulated during the heating operation thereby causing efficient performance during both operations.

As well as decreasing the system flow during the heating operation my novel capillary tube arrangement also provides an additional advantageous result. Due to the smaller flow caused by the heat exchange during the heating operation, the system must of course move to a different steady state condition than during the cooling operation. This difference in steady state condition is of course accompanied by a different evaporator pressure than during the cooling operation. Specifically with less refrigerant flowing during the steady state condition of the heating cycle, the pressure in the evaporator, outside coil 8, is lower than it would be if a conventional capillary without my novel heat exchange means were used. This decrease in evaporator pressure is advantageous because as a direct corollary it means a lower evaporator temperature; and the lower the evaporator temperature the more heat may be picked up the evaporator for a given rate of flow. Thus not only does my improved capillary tube arrangement provide for a decreased flow during the heating cycle, but also it results in a lower evaporator temperature than would exist if my novel heat exchange means were not employed therefore providing more efficient heat transfer between the cold outside air and coil 8.

While in accordance with the patent statute I have described what at present is considered to be the preferred embodiment of my invention, it will be understood to those skilled in the art that various changes and modifications may be made therein without departing from my invention and, I, therefore, aim in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In a reversible cycle refrigerating system for heating and cooling air for an enclosure, a compressor, first and second heat exchangers, a capillary tube connected between said heat exchangers and serving to expand re-

refrigerant from condensing pressure to evaporating pressure during both the heating and the cooling cycle, means for selectively connecting the discharge and the suction of said compressor to said first and second heat exchangers respectively during the heating cycle and to said second and first heat exchangers respectively during the cooling cycle, said means including first and second conduits connected respectively to said first and second heat exchangers and a reversing valve connected to said conduits and to said compressor discharge and suction, said first conduit carrying hot discharge refrigerant from said compressor during said heating cycle and cool suction refrigerant to said compressor during said cooling cycle, and said first conduit being arranged in heat transfer relation with at least a part of said capillary tube for cooling said capillary tube during said cooling cycle and heating said capillary tube during heating cycle whereby the formation of gaseous refrigerant in said capillary tube is retarded during said cooling cycle and quickened during said heating cycle causing said capillary tube to be less effective to pass refrigerant during said heating cycle and effecting a lower refrigerant flow rate through said system.

2. In a reversible cycle refrigerating system for heating and cooling air for an enclosure, a compressor, an indoor coil and an outdoor coil, a capillary tube connected between said coils and serving to expand refrigerant from condensing pressure to evaporating pressure during both the heating and the cooling cycle, means for

selectively connecting the discharge and the suction of said compressor to said indoor and outdoor coils respectively during the heating cycle and to said outdoor and indoor coils respectively during the cooling cycle, said means including first and second conduits connected respectively to said indoor and outdoor coils and a reversing valve connected to said conduits and to said compressor discharge and suction, said first conduit carrying hot discharge refrigerant from said compressor during said heating cycle and cool suction refrigerant to said compressor during said cooling cycle, and said first conduit being arranged in heat transfer relation with at least a part of said capillary tube for cooling said capillary tube during said cooling cycle and heating said capillary tube during heating cycle whereby the formation of gaseous refrigerant in said capillary tube is retarded during said cooling cycle and quickened during said heating cycle causing said capillary tube to be less effective to pass refrigerant during said heating cycle and effecting a lower refrigerant flow rate through said system.

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