March 9, 1965 C. F. ALSING 3,172,272

AIR CONDITIONING APPARATUS

Original Filed Aug. 21, 1959

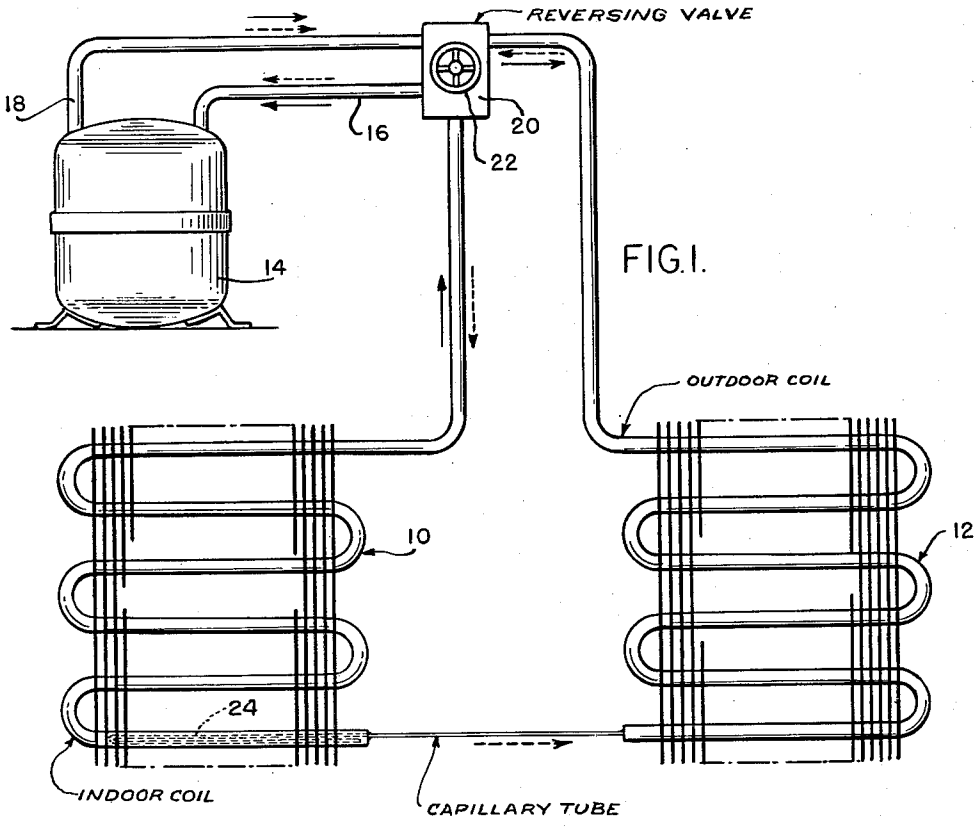


FIG.1.

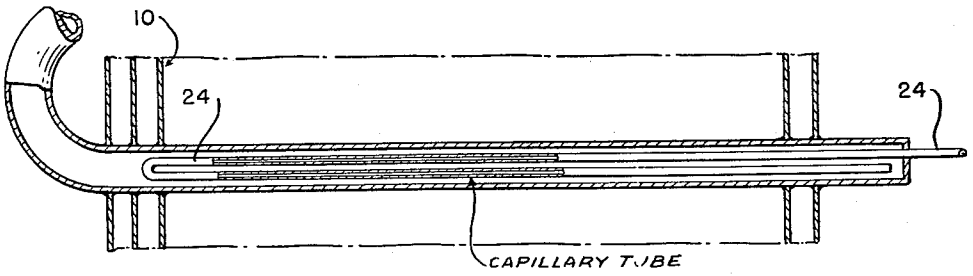


FIG.2.

WITNESS

Edward A. Sager

INVENTOR

CARL F. ALSING

BY William J. Daley

ATTORNEY

United States Patent Office

3,172,272
Patented Mar. 9, 1965

3,172,272

AIR CONDITIONING APPARATUS

Carl F. Alsing, Springfield, Mass., assignor to Westinghouse Electric Corporation, East Pittsburgh, Pa., a corporation of Pennsylvania

Continuation of abandoned application Ser. No. 835,205, Aug. 21, 1959. This application June 19, 1962, Ser. No. 205,177

4 Claims. (Cl. 62—324)

This invention relates to air conditioning apparatus and more particularly to a reversible heat pump system in air conditioning apparatus used for either heating or cooling air for comfort.

Conventional apparatus of the class set forth includes an indoor heat exchanger or coil which acts as an evaporator during the cooling operation, and an outdoor heat exchanger or coil which, at the same time, acts as a condenser. Conversely, during the heating operation the direction of refrigerant flow is reversed and the indoor coil acts as a condenser while the outdoor coil acts as an evaporator.

A slender, restricted bore tube is connected between the indoor and outdoor coils for the purpose of reducing the pressure, in either direction of flow between these heat exchangers. The tube is commonly known in the refrigeration art as a capillary tube.

A fixed flow restrictor that is a proper selection for the thermodynamic characteristics of the system during cooling operation is usually unsuitable for the system's efficient operation during heating operation. Unless the effective impedance of the capillary tube is greater during heating, the undesirable condition in which liquid refrigerant flows through to the compressor can result. This problem is well recognized in the refrigeration art and various means have been proposed previously to cope with it.

In dealing with this problem the present invention utilizes, in a unique arrangement, the well-known principle that the effective impedance of the restricted bore tube is increased by the vaporization of liquid refrigerant therein. In accordance with the invention, a portion of the capillary tube near its end connected to the indoor coil is arranged in heat transfer relationship with the refrigerant in a portion of the refrigerating system adjacent said end of the capillary tube and containing, during heating operation, refrigerant condensed in the indoor coil. This relationship may be established, for example, by inserting the end portion of the capillary tube in the run of the indoor coi to which the capillary tube is connected. This arrangement, in addition to providing increased effective impedance to flow during heating operation, to some extent adjusts or regulates the effective impedance to maintain within certain limits the quantity of liquid refrigerant present in the indoor coil.

The various objects, features and advantages of the invention will appear more fully from the detailed description which follows, taken in connection with the accompanying drawing, forming a part hereof, in which:

FIG. 1 is a diagrammatic view of a reversible refrigerating system embodying the invention; and

FIG. 2 is an enlarged sectional view of a fragmentary portion of FIG. 1, showing in detail the preferred arrangement of the capillary tube within the indoor coil.

The invention, as diagrammatically shown, is applied to a reversible heat pump system including an indoor coil or heat exchanger 10 and an outdoor coil or heat exchanger 12, both of which may be of the conventional cross-finned serpentine coil type. Although not shown, provision is made for conveying air over the coil 10 and delivering the same to the enclosure to be air conditioned. The coil 10 serves as the evaporator during cooling operation and as the condenser during heating operation. The outdoor coil 12 is placed in heat transfer relationship with the outside atmosphere and, here too, provision is made for conveying outside air over the coil 12 and discharging the same to outdoors or to some other place exterior of the enclosure. The coil 12 serves as the condenser during cooling operation and as the evaporator during heating operation.

In the illustrated embodiment of this invention, the runs or tubes of each coil are disposed horizontally and connected to provide a refrigerant path extending from the top through the successively lower, adjacent runs to the bottom of the coil so that, when the coil is serving as the condenser, gravity assists the condensed refrigerant in flowing to the bottom or extreme lower region of the coil.

The system further includes a motor-compressor 14 having a suction line 16 and a discharge line 18, both connected to a reversing valve 20. The reversing valve 20 is adapted to place the compressor suction line 16 and discharge line 18 in communication with the coils 10 and 12, respectively, for cooling the enclosure, and to reverse the connections and place them in communication with the coils 12 and 10, respectively, for heating the enclosure. Suitable provision is made for actuating the reversing valve 20, as by a manually movable knob 22.

A flow restrictor, which provides pressure reducing or expansion means, is connected between the indoor coil 10 and the outdoor coil 12. Preferably, the flow restrictor comprises a slender, restricted bore tube 24, commonly referred to in the art as a capillary tube. In FIG. 1, the flow of refrigerant during the cooling cycle is indicated by solid line arrows, and broken line arrows indicate the flow during the heating cycle.

In accordance with the present invention, the capillary tube 24 has a portion of its length, preferably an end portion near its connection to the indoor coil 10, placed in heat transfer relationship with a portion of the refrigerating system adjacent said end of the capillary tube connected to the indoor coil and containing, during heating operation, refrigerant condensed in the indoor coil. For example, said end portion of the capillary tube may be arranged in heat transfer relation with the run of the indoor coil 10 adjacent the connection (see FIG. 2). It is to be understood that a heat transfer relationship between the mentioned portions of the coil 10 and the capillary tube 24 can be established by various arrangements, such as by soldering portions of their respective tubes together; but, preferably, the end portion of the capillary tube 24 is doubled back on itself in a hairpin shape and inserted in the run of the coil 10, so that the end of the capillary tube is adjacent the connection between the tube and the coil. Refrigerant in a liquid state tends to collect at the end of its flow path in a condenser coil; and, by placing a length of the capillary tube 24 in intimate contact therewith, the flow of refrigerant

through tube 24 is affected by changing refrigerant conditions within the indoor coil **10**.

Theory of operation

The capillary tube conducts refrigerant from the coil acting as condenser to the coil acting as evaporator. It also expands refrigerant from condenser pressure to evaporator pressure; and the pressures within these coils are largely affected by their respective environmental air temperatures. Based on the average environmental air temperatures for which the refrigeration system is designed, as well as the compressor pumping rate (in lbs. per hour) and the surface area of each coil, the required effective impedance of the capillary tube is determined; and a suitable capillary tube which provides the required effective impedance is selected according to its length and bore. It is the general practice to make this selection on the basis of requirements for cooling operation of the circuit.

Although restricted bore tubes have been highly successful when used in refrigeration systems of the non-reversible type, they have presented special problems when employed in reversible refrigeration systems used in air conditioning apparatus for both heating and cooling. Principally the problem concerns thermodynamic efficiency, since an effective impedance which is correct for the cooling operation and one direction of refrigerant flow is all too often wrong for the heating operation when the direction of flow is reversed. In back of this problem is the fact that the range of environmental air temperatures for the coils is confined to a generally lower level for winter operation than for summer operation, and it follows that refrigerant on the suction side of the compressor will be less dense and the compressor will pump refrigerant into the condenser at a lower rate, weightwise, during winter operation. Also involved is the larger temperature difference between average indoor and outdoor temperatures during the winter time, which in turn, produces a larger pressure difference between the coils and across the capillary tube, which tends to increase the rate of refrigerant flow through the capillary tube. These two consequences of winter operation, namely, reduced refrigerant flow to the condenser and increased refrigerant flow from the condenser, tend to reduce the accumulation of refrigerant in the condenser. It follows that a capillary tube ideally suited for the cooling operation of the system may have an effective impedance so small that all liquid refrigerant will be emptied from the condenser and hot gas will flow from the condenser into the evaporator when the system is switched over to heating operation. And this is obviously objectionable. Therefore, it is the concern of the present invention to provide an arrangement in which the capillary tube will have a greater effective impedance during heating operation than during cooling operation.

Obviously, a capillary tube could be selected that would possess the proper impedance characteristics for heating operation but it would provide too great an impedance during most conditions of cooling operation. It may be mentioned in passing that a capillary tube should not provide too great an impedance or else the evaporator will be starved and the condenser will be flooded. In such a situation, both coils operate at reduced heat transfer efficiency, and the compressor also operates at a lower efficiency.

With the present invention, a portion of the capillary tube **24** is inserted within the indoor coil **10** where it is in heat transfer relationship with the refrigerant therein, which arrangement changes the effective impedance of the tube. When the inserted portion of the tube is cooled, heat is extracted from the refrigerant flowing therethrough and this negatives to some extent the flow impedance of this inserted tube portion by inhibiting further vaporization of the refrigerant and promoting its condensation. Conversely, adding heat to the refrigerant flowing through the capillary tube promotes its vaporization and thereby increases the effective impedance of the tube. Although this principle is well known in the refrigeration art and has been used in one way or another in prior art reversible cycle systems, the present arrangement is unique in placing a portion of the capillary tube in heat transfer relationship with the portion of the indoor coil near the connection between the indoor coil and the tube.

Cooling operation

During cooling operation of the system condensed liquid refrigerant leaves the outdoor coil **12**, which is acting as a condenser, and enters the capillary tube **24** at substantially the discharge pressure of the motor-compressor **14**. While traveling through the uninserted length of capillary tube **24**, which is surrounded by air, a small but progressively increasing portion of liquid refrigerant vaporizes as its pressure is progressively reduced. This progressively increases the effective impedance of each unit length of the capillary tube as the refrigerant approaches the outlet end of the tube.

However, the impedance offered by that portion of the capillary tube which is bathed in cool refrigerant in the indoor coil **10** is considerably less than the impedance which this same portion of the tube would offer if it were not so cooled because the lower temperature to which it is subjected inhibits further vaporization of refrigerant flowing through the capillary tube. This enables the designer of the system to select for conditions of cooling operation a somewhat longer or more restricted capillary tube, which is then available to offer additional impedance during heating operation.

Heating operation

It will now be assumed that the system is operating at an ideal flow rate to heat an enclosure and the indoor coil **10** is acting as a condenser. Under such conditions, liquid refrigerant in the condenser covers the inlet to the capillary tube **24**, thus serving to keep gaseous refrigerant from entering the capillary tube.

As liquid refrigerant flows through the capillary tube **24**, expansion and cooling thereof takes place and additional heat is absorbed from the warm liquid refrigerant in the indoor coil **10**. The additional heat imparted to the refrigerant in the capillary tube causes this refrigerant to commence to vaporize sooner in its travel through the capillary tube and increases the effective impedance of the capillary tube over what it would be were this portion of the capillary tube not so heated.

It can thus be seen that a capillary tube having an end portion thereof in heat transfer relationship with refrigerant at this one end of the indoor coil offers substantially greater impedance to refrigerant flow during heating operation than during cooling operation. The impedance of the capillary tube is thereby more nearly matched to the flow rate of refrigerant through the other components of the system during heating to insure that a liquid seal will always be maintained at the outlet of the indoor coil.

Regulating feature

It is well understood in the refrigeration art that the condenser component of a refrigerating or heat pumping system functions most efficiently when the level of liquid refrigerant therein is at, or near, the outlet end of the condenser. If additional passes or runs of the condenser are permitted to become filled with liquid refrigerant less surface area is available on which vaporous refrigerant can be condensed. The heat exchange relationship between a portion of the capillary tube **24** and the refrigerant within one pass of the indoor coil **10** provides for regulation of the amout of liquid refrigerant which accumulates in the indoor coil for a given range of operating conditions to which the apparatus is subjected.

As mentioned previously, the effective impedance of

the capillary tube **24** is increased when the system is placed in heating operation so as to prevent all of the liquid refrigerant from leaving the indoor coil **10**. This increase of impedance is effected by the addition of heat to refrigerant flowing through the capillary tube. It can be readily appreciated that as the "liquid level" in the indoor coil **10** approaches the outlet end of the last pass of the coil a greater length of the capillary tube **24** is exposed to vaporous refrigerant in the coil. This results in more heat being added to this inserted portion of the capillary tube; first, because the heat of condensation is available from the vaporous refrigerant and secondly, because the vaporous refrigerant is warmer than the liquid refrigerant, which is subcooled to some extent. Thus, as operating conditions change, for example, the outdoor air temperature falls, and refrigerant begins to flow more rapidly through the capillary tube **24**, the "liquid level" in the coil **10** falls, exposing an increasing length of the capillary tube to warm vaporous refrigerant which, in turn, heats and increases the effective impedance of the capillary tube. Eventually, a state of equilibrium is reached and the "liquid level" stabilizes at some point near the outlet of the indoor coil.

When conditions change so as to cause the "liquid level" to rise in the indoor coil **10**, say, for example, the outdoor temperature rises rapidly, more of the inserted portion of the capillary **24** will become covered with liquid refrigerant. The quantity of heat available to be added to this portion of the capillary tube becomes less as less vaporous refrigerant remains in contact with the capillary tube. Depending upon the degree of change of conditions, the "liquid level" will stabilize at a higher point in the indoor coil **10** as the effective impedance of the capillary tube **24** is reduced to match the flow conditions of the system.

In a properly designed system this movement of the "liquid level" can be confined to that portion of the indoor coil which contains the inserted portion of the capillary tube **24**, so that only this lower or last run of the indoor coil is likely to be flooded with liquid refrigerant, thereby leaving the remainder of the indoor coil available as condensing surface area.

Conclusion

From the foregoing it will be apparent that arranging a portion of the capillary tube **24** in heat transfer relation with refrigerant in the indoor coil **10** not only has the general effect of increasing the effective impedance of the tube during heating, but also accomplishes regulation of the effective impedance of the capillary tube during heating operation in response to refrigerant conditions within the coil **10**.

It will be appreciated that the ideal length and bore of a capillary tube, as well as the ideal amount thereof to be inserted, varies with the capacity of the refrigeration system and expected ambient conditions. However, in one working model of a room air conditioner having a cooling capacity of approximately three-quarter ton and embodying the present invention, a capillary tube 36 inches long and having a bore .059 inch in diameter was effectively employed with 16 inches of its length inserted in the indoor coil **10**.

While the invention has been shown in but one form, it will be obvious to those skilled in the art that it is not so limited, but is susceptible of various changes and modifications without departing from the spirit thereof.

This application is a continuation of application Serial No. 835,205, filed August 21, 1959.

What is claimed is:

1. In a reversible system for heating and cooling air for an enclosure,
   a compressor,
   a first heat exchanger for conditioning enclosure air,
   a second heat exchanger in heat transfer relationship with outdoor air,
   means including a reversing valve for selectively connecting the discharge and the suction of said compressor to said first and second heat exchangers respectively during heating operation and to said second and first heat exchangers respectively during cooling operation, and
   a capillary tube connected between said heat exchangers and serving to expand refrigerant from condensing pressure to evaporating pressure during both the heating and the cooling operations, said capillary tube being out of heat transfer relationship with the refrigerant flowing through said second or outdoor heat exchanger, said capillary tube having a portion thereof in heat transfer relationship with a portion of the refrigerating system adjacent the end of the capillary tube connected to the first heat exchanger and containing, during heating operation, refrigerant condensed in said first heat exchanger, whereby the flow rate of refrigerant through the refrigerating system is lower during heating operation than during cooling operation.

2. In a reversible system for heating and cooling air for an enclosure,
   a compressor,
   a first heat exchanger for conditioning enclosure air,
   a second heat exchanger in heat transfer relationship with outdoor air,
   means including a reversing valve for selectively connecting the discharge and the suction of said compressor to said first and second heat exchangers respectively during heating operation and to said second and first heat exchangers respectively during cooling operation, and
   a capillary tube connected between said heat exchangers and serving to expand refrigerant from condensing pressure to evaporating pressure during both the heating and the cooling operations, said capillary tube being out of heat transfer relationship with the refrigerant flowing through said second or outdoor heat exchanger, said capillary tube and said first heat exchanger having portions thereof near the connection therebetween arranged in heat transfer relationship for regulating the flow rate of refrigerant through said refrigerating system.

3. In a reversible system for heating and cooling air for an enclosure,
   a compressor,
   a first heat exchanger for conditioning enclosure air,
   a second heat exchanger in heat transfer relationship with outdoor air,
   means including a reversing valve for selectively connecting the discharge and the suction of said compressor to said first and second heat exchangers respectively during heating operation and to said second and first heat exchangers respectively during cooling operation, and
   a capillary tube connected between said heat exchangers and serving to expand refrigerant from condensing pressure to evaporating pressure during both the heating and the cooling operation, said capillary tube being out of heat transfer relationship with the refrigerant flowing through said second or outdoor heat exchanger and having a substantial portion thereof adjacent the connection to said first heat exchanger inserted in a portion of said first heat exchanger so that a heat transfer relationship is established between said capillary tube portion and the refrigerant in said first heat exchanger portion, whereby the rate of refrigerant flowing through said capillary tube is regulated.

4. In a reversible system for heating and cooling air for an enclosure,
   a compressor,
   a first heat exchanger for conditioning enclosure air,

a second heat exchanger in heat transfer relationship with outdoor air,

means including a reversing valve for selectively connecting the discharge and the suction of said compressor to said first and second heat exchangers respectively during heating operation and to said second and first heat exchangers during cooling operation, and

a capillary tube connected between said heat exchangers and serving to expand refrigerant from condensing pressure to evaporating pressure during both the heating and the cooling operation; said capillary tube being out of heat transfer relationship with the refrigerant flowing through said second or outdoor

heat exchanger and having one end connected to said second heat exchanger, and another end including a substantial length of tube adjacent thereto inserted in said first heat exchanger, whereby a heat transfer relationship for regulating the flow rate of refrigerant through said refrigerating system is established between the refrigerant in the inserted length of said capillary tube and the refrigerant in said first heat exchanger.

References Cited in the file of this patent

UNITED STATES PATENTS

2,750,762	Coyne	June 19, 1956
2,956,421	Stevens	Oct. 18, 1960