

[54] REFRIGERATOR WITH CAPILLARY CONTROL MEANS

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[52] U.S. Cl.....62/222, 62/276, 62/511
[51] Int. Cl.....F25b 41/04
[58] Field of Search62/511, 198-200, 62/222

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[57] ABSTRACT

A refrigerator having a refrigerating vessel divided into a plurality of compartments comprising either cold storage compartments or at least one cold storage compartment and one freezing compartment each of which is provided with an evaporator for the refrigeration thereof. Capillary tubes are provided for supplying the refrigerant to the individual evaporators in the compartments, and heating coils are wound around portions of the capillary tubes. An electric current is caused to flow through the heating coils in order to provide individual control of the supply of the quantity of refrigerant.

2 Claims, 7 Drawing Figures

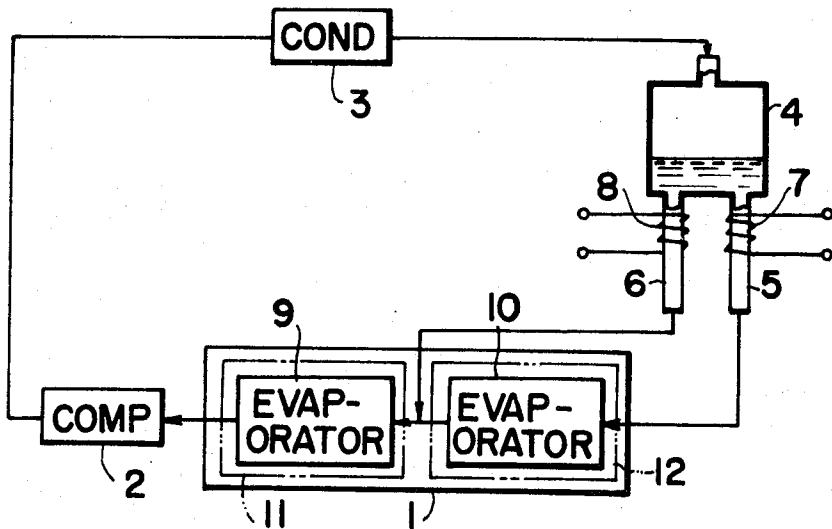


FIG. 1

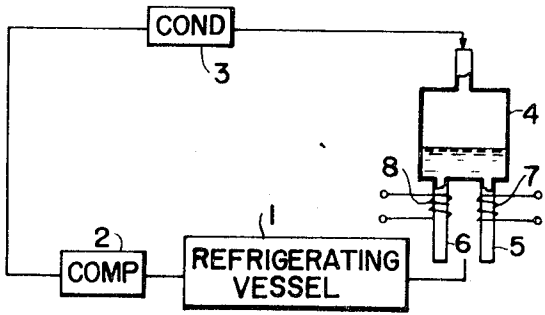


FIG. 2

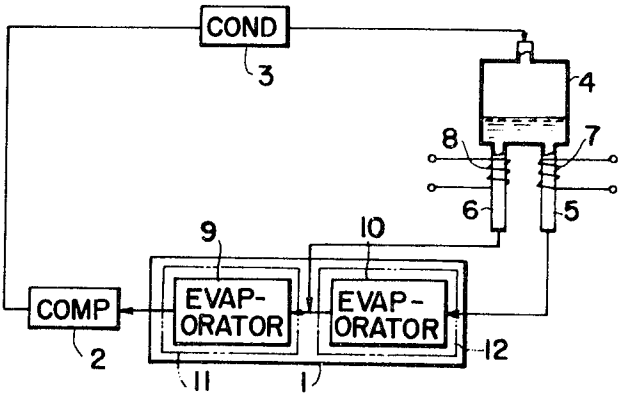
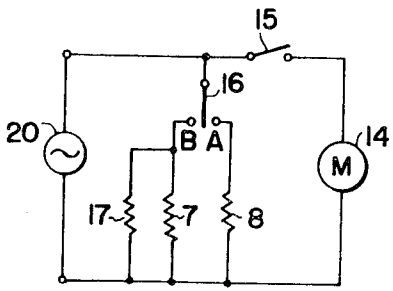


FIG. 3



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FIG. 4

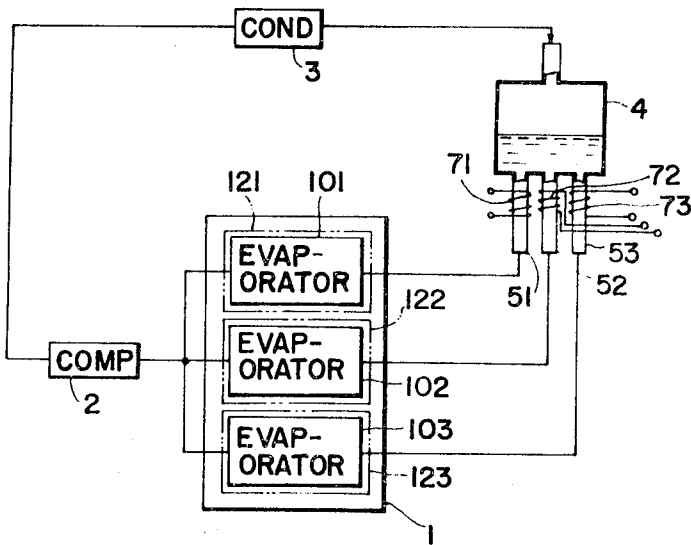
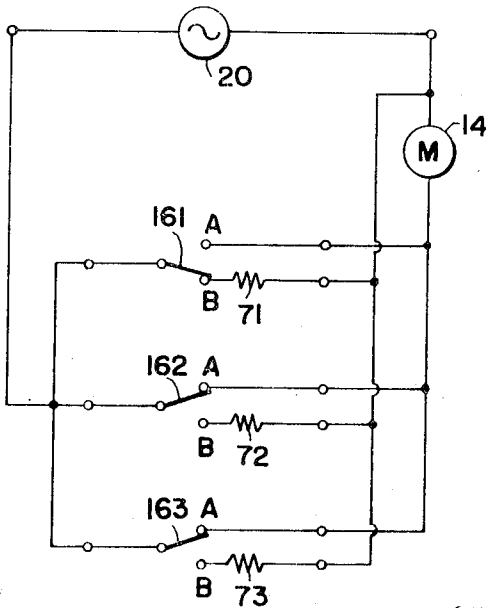


FIG. 5



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FIG. 6

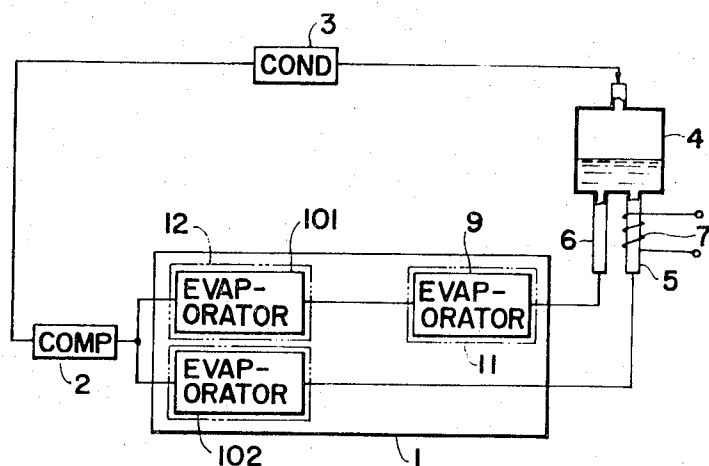
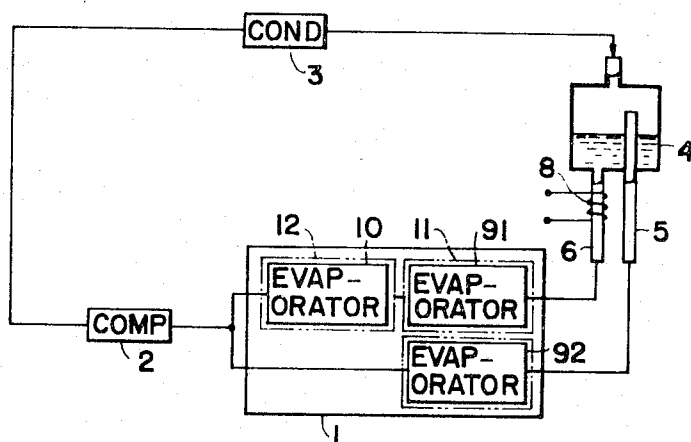


FIG. 7



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REFRIGERATOR WITH CAPILLARY CONTROL MEANS

BACKGROUND OF THE INVENTION

The present invention relates to a refrigerator, and more particularly, to a refrigerator having at least a plurality of cold storage compartments for storing perishable foods or necessities of life at low temperatures or at least one cold storage compartment and one freezing compartment where foods are stored in a frozen state.

In general, refrigerators are constructed so that a refrigerant used therein is liquefied by a compressor and a condenser and is then gasified as it passes through evaporators, thus carrying off the heat from the cold storage and freezing compartments in the form of heat of vaporization and thereby producing lower temperatures in those compartments.

Since it is usually necessary to maintain the cold storage compartment at a temperature of about $+5^{\circ}\text{C}$. and the freezing compartment at about -20°C ., the compartments are equipped with separate evaporators. With such an arrangement, the difference in the rate of heat leakage into the cold storage and freezing compartments in summer and winter weather creates a problem.

If, for example, the average temperature in summer is 30°C . and that in winter is 10°C ., the difference between the temperature inside a freezing compartment kept at -20°C . and the temperature of the atmosphere surrounding the refrigerator is 50°C . in summer and is 30°C . in winter months. Therefore, the ratio of the amount of heat which enters into the freezing compartment from the outside in summer to that of heat in winter is about 1:30/50.

On the other hand, the ratio of the amount of heat which leaks into a cold storage compartment from the surrounding atmosphere in summer weather to that of heat in winter weather is about 1.5/25. The above calculations demonstrate that, whereas the heat leakage into the freezing compartment varies little throughout the year, the amount of heat which leaks or enters into the cold storage compartment is fairly dependent upon the temperature of the surrounding atmosphere.

Thus, in order to maintain the temperatures inside the freezing and cold storage compartments so as to be virtually constant notwithstanding the variations in the temperature of the surrounding atmosphere thereof, it is necessary to provide individual temperature-detecting means at these compartments and to regulate the flow rate of the refrigerant supplied to the evaporators in accordance with the output signal of such detecting means. In the past, the regulation of the flow rate has been conventionally accomplished by the use of magnetic valves which are both expensive and apt to cause mechanical troubles.

Furthermore, in a refrigerator having such freezing and cold storage compartments, it is frequently necessary to disconnect the refrigerant for the cold storage in order to melt away the accumulated frost on the evaporators thereof whereas the supply of the refrigerant for the freezing compartment is being continued so as to keep the foods or the like frozen. In such a case, the independent control of the flow rates to the respective evaporators is required. It is also necessary to independently control the temperature in each compartment of the refrigerator having a plurality of cold storage compartments which are provided with separate doors for the independent opening and closing thereof. To meet the foregoing requirements, it has been customary to use expensive magnetic valves as before mentioned.

SUMMARY OF THE INVENTION

It is therefore the aim of the present invention to provide a refrigerator of the aforementioned type in which the temperature inside the cold storage compartment and the freezing compartment or a plurality of cold storage compartments can be controlled independently and with extreme simplicity.

The underlying problems are solved in accordance with the present invention by equipping the refrigerator with a tank for

temporarily storing the liquefied refrigerant, capillary tubes which serve as flow passages for the supply of the refrigerant from the tank to the evaporators disposed separately in the cold storage and freezing compartments, and heating coils wound around parts of the capillary tubes in such a manner that the flow rates of the refrigerant supplied to each of the individual evaporators can be regulated by controlling the current flowing through the heating coils.

Another object of the present invention is to provide a refrigerator constructed in such a manner so as to perform the temperature control through the regulation of the flow rate of the refrigerant by inexpensive and positive-acting means instead of expensive and troublesome control means such as magnetic valves.

BRIEF DESCRIPTION OF THE DRAWINGS

These and further objects, features and advantages of the present invention will become more apparent from the following description when taken in conjunction with the accompanying drawings showing embodiments thereof for purposes of illustration only, and wherein:

FIG. 1 is a schematic diagram of the basic construction of the present invention;

FIG. 2 is a schematic diagram illustrating one embodiment of the invention;

FIG. 3 is a schematic diagram of the electrical circuit for the embodiment shown in FIG. 2;

FIG. 4 is a schematic diagram illustrating another embodiment of the invention;

FIG. 5 is a schematic diagram of the electrical circuit for the embodiment of FIG. 4; and

FIGS. 6 and 7 are schematic diagrams of still further embodiments of the invention.

DETAILED DESCRIPTION OF THE DRAWINGS

Referring now to the drawings and more specifically to FIG. 1, a refrigerating vessel, which is generally indicated at 1, is divided into at least two independent compartments, each having an evaporator. Sometimes one of the evaporators is associated with the cold storage compartment and the other is associated with the freezing compartment. In other constructions, the evaporators are disposed at separate cold storage compartments, respectively.

A compressor 2 is driven by an electric motor to compress the refrigerant flowing out of the evaporators in the refrigerating vessel 1. A condenser 3 then condenses the compressed refrigerant to a liquid form. The liquefied refrigerant is then led to a tank 4, which serves as a temporary storage means for the balance of the amounts of the refrigerant being supplied from the condenser 3 and leading to the capillary tubes 5 and 6. Therefore, the flow passage having a larger-than-usual diameter may be used as the tank means 4.

Heating coils 7 and 8 are wound around the inlet end portions of the capillary tubes 5 and 6. A power source (not shown) is connected with the coils 7 and 8 to supply a current thereto. The refrigerant from the capillary tubes 5 and 6 is supplied to the separate evaporators for the refrigerating vessel 1 and, with the heat of vaporization, reduces the temperatures in the individual compartments, for example, the cold storage and freezing compartments.

Generally, the flow rate of a refrigerant flowing through a capillary tube varies in accordance with the inside diameter and the length of the tube as well as the pressure difference between the inlet and outlet thereof. When the inside diameter and the length and inlet-outlet pressure difference of the capillary tube are constant, the flow rate of the refrigerant flowing therethrough depends largely upon whether the refrigerant is in a liquid state or gaseous state or in its mixture state. Since the refrigerant in a gasified state has a far greater volume per unit weight than in a liquefied state, the former will be required to have extremely high velocity if it is to flow at the same rate under the same conditions as the latter state.

Such a high flow velocity will cause a sharp increase in the frictional resistance of the capillary tube, and if the pressure difference between the inlet and outlet remains unchanged, the gaseous refrigerant will flow at a minimum rate.

As it flows through a capillary tube, the refrigerant in a liquid state is reduced in pressure due to the frictional loss. Thus, if the pressure of the refrigerant is reduced below the saturation pressure at the temperature thereof, a part of the liquid refrigerant evaporates to a gaseous state. The amount of this gasified refrigerant increases at the approach of the stream to the outlet of the capillary tube.

If the refrigerant is in the supercooled state at the inlet of each capillary tube, the gasifying point is shifted closer to the outlet, and the flow rate of the refrigerant in that state becomes close to the flow rate of the refrigerant liquid throughout the length of the capillary tube.

If the refrigerant at the inlet of a capillary tube is in a saturated liquid state, the gasification is initiated at a point closer to the inlet of the tube, so that from 20 to 40 percent at the ratio by weight of the gaseous refrigerant is mixed in the liquid refrigerant stream. The flow rate of the mixture is about four to six times as much as that of the refrigerant which is gasified throughout the length of the capillary tube.

If the gaseous refrigerant is already mixed at the inlet of a capillary tube, the rate of the gasified component to liquefied component inside the tube is increased accordingly, and the flow rate becomes close to that of the refrigerant which is gasified throughout the length of the capillary tube.

In the case of the refrigeration cycle of a household refrigerator, the refrigerant at the inlet of each capillary tube is in an almost saturated liquid state. Therefore, a flow rate of the refrigerant flowing through the capillary tube is four to six times as much as that of the refrigerant kept in a gasified state throughout the length of the tube, as described in detail above.

Thus, if an electric current flows through the heating coils around the inlet end portions of the capillary tubes 5 and 6 of the apparatus shown in FIG. 1 thereby forcibly heating the inlet portions, the liquefied refrigerant will then be partially gasified so that the quantity of the refrigerant flowing through the capillary tubes may be decreased correspondingly. If the amount of heat is increased, for example, to about 10 watts for a refrigerator having a capacity of 100 liters, the refrigerant at the inlets of the capillary tubes will be mostly in the gasified state and flow rates of the refrigerant therethrough may be reduced to one-fourth through one-sixth of the usual rates.

Therefore, in the apparatus of the present invention the flow rates through the capillary tubes 5 and 6 can be regulated by the control of the current flowing through the heating coils 7 and 8. As a consequence, the amounts of refrigerant to be supplied to the evaporators (not shown) of the refrigerating vessel 1 are varied, so that the temperatures in the cold storage and freezing compartments can be controlled freely and independently with respect to each other.

The possibility of independently varying the temperatures inside the cold storage and freezing compartments in the manner described above is extremely helpful in defrosting either compartment while, at the same time, refrigerating the other compartment. FIG. 2 is a schematic representation of a refrigerator provided with such a defrosting means. A freezing compartment or frozen food space 11 contains an evaporator 9, to which the refrigerant is supplied from a capillary tube 6 in order to maintain the compartment normally at a temperature of about -20°C . A cold storage compartment is indicated at 12. An evaporator 10 is disposed in this cold storage compartment and is supplied with the refrigerant from a capillary tube 5 to maintain the cold storage compartment normally at a temperature of about $+5^{\circ}\text{C}$. The refrigerant that has passed through the evaporator 10 is fed to the evaporator 9 and serves to refrigerate freezing compartment 11. Heating coils 7 and 8 are wound around the capillary tubes 5 and 6 at portions close to the inlets for the refrigerant, in such a manner that they can heat the tube portions and hence regulate the flow rates of the refrigerant being supplied to the evaporators 10 and 9, respectively.

One example of a main electric circuit for the above type of refrigeration cycle will now be described with reference to FIG. 3. In the circuit of FIG. 3, numeral 14 represents a motor coil for the compressor 2, and numeral 15 represents contacts for a temperature controller (not shown) which are designed to close the circuit when the temperature of the cold storage compartment or the freezing compartment exceeds the predetermined level and also to open the circuit when the temperature of the compartment falls below the predetermined level.

A defrosting switch 16 is closed by a contact A during normal operation of the refrigerator. When the cold storage compartment 10 is to be defrosted, the switch 16 is set to contact B in response to a defrosting signal generated either manually or automatically. As the switch 16 is closed on the contact A, a current from a power source 20 is fed to the heating coil 8 and the quantity of the refrigerant flowing through the capillary tube 6 is thereby restricted. Conversely, if the switch 16 is closed on the contact B, a current is fed to the heating coil 7 so as to limit the flow of the refrigerant through the capillary tube 5, and at the same time a current is supplied to a defrosting heater 17 which is associated with the evaporator 10 for the cold storage compartment.

The operation of the apparatus illustrated in FIGS. 2 and 3 is as follows: During normal operation of the refrigerator, the switch 16 is closed on the contact A side and therefore the capillary tube 6 is kept warm so that the flowing of the refrigerant through the tube is maintained at a very low level. The refrigerant from the tank 4 passes through the capillary tube 5 into the evaporators 10 and 9, respectively, of the cold storage compartment 12 and the freezing compartment 11, thereby producing and maintaining low temperatures in both the compartments as desired.

For the defrosting of the cold storage compartment 12, the switch 16 is turned on to the contact B either by hand or automatically. As a result, the capillary tube 5 is heated and the flow rate of the refrigerant through the tube is reduced to an extremely low level. Meanwhile, the refrigerant is supplied to the evaporator 9 of the freezing compartment through the tube 6 for continuous refrigeration thereof. Simultaneously on switching to the contact B a current flows through the defrosting heater 17 associated with the cold storage compartment so as to heat the compartment temporarily for defrosting purposes. Thus, in the apparatus according to the present invention, the defrosting of the cold storage compartment can be accomplished with utmost ease while the freezing compartment is still being refrigerated.

In FIG. 4, another embodiment of the invention is illustrated which is so constructed that a single compressor permits independent temperature control of a plurality of cold storage compartments. As shown, evaporators 101, 102, 103 are located, respectively, inside cold storage compartments 121, 122, 123, and the refrigerant supplied to these evaporators through capillary tubes 51, 52, 53, respectively. The cold storage compartments 121, 122, 123 are equipped with separate doors, in such a manner that the opening of any door will not cause a leakage of heat from the outside into any other cold storage compartment.

The main electrical circuit of the apparatus of FIG. 4 is constructed, for example, in accordance with the diagram in FIG. 5. In that diagram, switches 161, 162, 163 are actuated either automatically by temperature detectors (not shown) disposed in the cold compartments 121, 122, 123, respectively, or manually. Each switch is turned on to the contact A when the temperature in the related cold storage compartment is above a predetermined value, or is turned on to the contact B when the temperature has not yet reached the predetermined value.

For example, if the temperature in the cold storage compartment exceeds the desired value, the switch 161 is closed on to the contact A and no current flows through the heating coil 71. Accordingly, the refrigerant is fed to the evaporator 101 via the capillary tube 51, thereby refrigerating the cold storage compartment 121. As the temperature of the cold storage compartment 121 is thus reduced to a value below the

predetermined level, the switch 161 is turned on to the contact B and the current from the power source 20 is fed to the heating coil 71. As a result, the capillary tube 51 is partially heated so the quantity of the refrigerant supplied to the evaporator 101 is greatly decreased. In this manner, the temperature inside the cold storage compartment is maintained at the predetermined level.

As long as any one of the switches 161, 162, 163 is closed on the contact A side, the current flows through the motor coil 14 and the compressor 2 is kept in operation. However, if all of the switches 161, 162, 163 are closed on the contact B side, the current will no longer flow through the motor coil 14 and the compressor operation will be brought to a stop.

While the freezing compartment in a conventional household refrigerator is influenced very little by the temperature of the surrounding atmosphere, as already described, the cold storage compartment is affected easily by the variations in the temperatures thereof. The use of the means for controlling the flow rates of the refrigerant according to the present invention makes it possible to provide with ease a refrigerator in which the temperature of the cold storage compartments can be maintained at constant and optimum levels in every season of the year.

FIG. 6 shows still another embodiment of the invention which is also intended to overcome the above-mentioned disadvantages. In this embodiment, the refrigerant from a capillary tube 6 passes through the evaporator 9 of a freezing compartment 11 and then to an evaporator 101 of a cold storage compartment 12 into a compressor 2. On the other hand, the refrigerant from a capillary tube 5 is directly supplied to an evaporator 102 of the cold storage compartment 12 and is then introduced into the compressor 2. Here, the heating coil is wound only around the capillary tube 5.

In summer weather, no current is applied to the heating coil, but in winter weather a current flows through the coil. This means that the refrigerant is supplied to both the evaporators 101, 102 in summer months so that the cold storage compartment 12 may be adequately refrigerated. In winter months, the capillary tube 5 is heated and therefore the quantity of the refrigerant that passes therethrough is greatly reduced. Accordingly the cold storage compartment is refrigerated merely by the refrigerant passing through the evaporator 9 along so that the excessive refrigeration therein can be avoided.

While two evaporators are used for the cold storage compartment in the above-described embodiment, a refrigerator with the same desired refrigerating effect may be obtained by the use of two evaporators in the freezing compartment thereof.

An example of such design is illustrated in FIG. 7. The refrigerant from a capillary tube 6 passes through an evaporator 91 of a freezing compartment and then through an evaporator 10 of a cold storage compartment 12 into a compressor 2. On the other hand, the refrigerant from a capillary tube 5 passes through an evaporator freezing compartment 11 into the compressor 2. The capillary tube 6 is connected to the bottom of a tank 4 and is partially surrounded by a heating coil 8. The other capillary tube 5 extends upwardly inside the tank

4. Normally, the refrigerant is supplied from the tube 6 connected to the bottom of the tank into the evaporators 91 and 10 to produce low temperatures in the freezing compartment 11 and the cold storage compartment 12, respectively. As the temperature in the cold storage compartment 12 drops below the predetermined level, a current flows through the heating coil 8 so that capillary tube 6 is partially heated. Therefore, the amount of the refrigerant that flows out of the tube becomes extremely small. Accordingly, the liquid refrigerant in the tank 4 is gradually increased until it overflows into the capillary tube 5. In this state, liquid refrigerant is supplied to the evaporator 92 and the freezing compartment 11 is continuously refrigerated while the cold storage compartment 12 is refrigerated merely by the negligible amount of the refrigerant so that the compartment 12 is prevented from being supercooled.

While the present invention has so far been described in detail in conjunction with some illustrative embodiments thereof, it should be understood that, in brief, numerous other modifications are possible without departing from the spirit and scope of the invention that the flow rate of the refrigerant is controlled by partial heating of the capillary tubes.

I claim:

1. A refrigerator comprising,
 - a refrigerating vessel divided into a cold storage compartment and a freezing compartment, each including at least one evaporator for gasifying refrigerant passed therethrough and thus for refrigerating the corresponding compartment, respectively;
 - a compressor for compressing the refrigerant from said individual evaporators;
 - a condenser for liquefying the compressed refrigerant by said compressor;
 - refrigerant supplying means including first and second capillary tubes for providing the refrigerant from said condenser to each of said evaporators in such a manner that the refrigerant that has passed through the first capillary tube is then introduced into the evaporator of said cold storage compartment then into said evaporator of said freezing compartment and brought back to said compressor, while the refrigerant passed through said second capillary tube is recycled to said compressor through said evaporator of said freezing compartment;
 - heating means including heating coils wound around the respective capillary tubes for heating said capillary tubes; and
 - control means for controlling supply of electric current to said heating coils, whereby different temperatures are provided to said compartments.

2. A refrigerator according to claim 1, wherein said cold storage compartment is provided with a defrosting means which, during normal operations, heats a portion of said second capillary tube to limit the flow rate therethrough and, for defrosting, restricts the flow rate of the refrigerant through said first capillary tube and, at the same time, heats said cold storage compartment.

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