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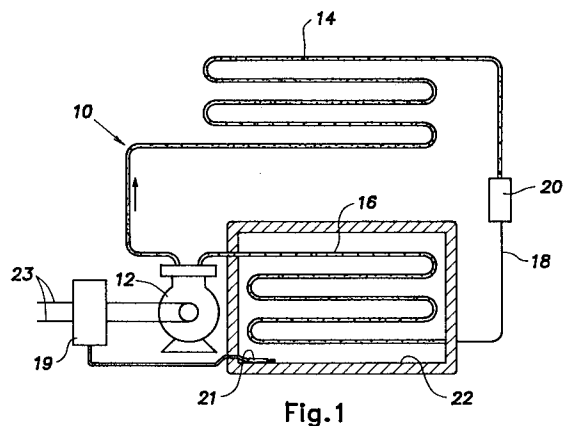
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(54) **Refrigerator system with subcooling flow control valve.**

(57) A vapor compression refrigeration system (10) for cooling a cabinet (22) having a thermostat (19) for cycling the compressor (12) off and on to maintain a predetermined temperature range in the cabinet (22) includes a subcooling flow control valve (20) at the inlet to the capillary tube restriction (18). The valve (20) is operated by a sealed bellows (40) containing a refrigerant so that the valve (20) is responsive to the fluid entering the valve (20). The valve (20) is calibrated so that only a subcooled liquid refrigerant can flow through the valve (20) and if the entering refrigerant is above a predetermined level the valve (20) will close to completely block all flow between the condenser (14) and the evaporator (16), and the valve (20) will stay in the closed position at all times when the compressor (12) is not running.



BACKGROUND OF THE INVENTION

This invention relates to refrigeration systems, and more particularly to refrigeration systems used in household refrigerators and freezers.

Refrigeration systems for household refrigerators and freezers have heretofore been designed for low cost and high reliability, both of which require a simplicity of design, together with a minimum number of parts. Typical refrigerators or freezers employ a vapor-compression system having a fractional horsepower, electric motor driven, hermetic compressor connected in a circuit with a condenser, an evaporator, an optional accumulator, and a refrigerant flow restriction between the condenser and the evaporator. For reasons of obtaining high energy efficiency, it is desirable to utilize a relatively high duty cycle for the compressor run time, while maintaining a sufficient reserve for high ambient temperature conditions. Thus, a thermostat responsive to the temperature in the cooled cabinet is used to cycle the compressor as necessary to maintain the preselected temperature. Based on normal room temperatures and the absorption of heat into the cooled space through the insulation, the compressor duty cycle may run fifty percent to sixty percent, leaving a reserve but requiring continuous operation under very high ambient temperatures or frequent opening of the door for access to the interior of the cooled cabinet.

The flow restriction has been almost universally a capillary tube sized for optimal efficiency at a single set of conditions of ambient and internal cabinet temperature. Capillary tubes used as the sole restriction offer the advantages of low cost, high reliability, and the added efficiency of being easily placed in heat exchange relationship with the return line from the evaporator to the compressor.

The capillary tube system, which runs constantly at a single ambient temperature and constant load condition, is very efficient when the capillary tube is sized for these conditions. When this is done and the system is operating under equilibrium conditions, the refrigerant at the condenser outlet where it enters the capillary tube is a saturated or slightly subcooled liquid. This liquefied refrigerant flows through the capillary tube and undergoes a substantial pressure reduction until it enters the evaporator, where it is vaporized to absorb heat from the interior of the refrigerator or freezer.

Because the refrigerant flows in a closed system, and the actual rate of flow through the capillary tube is dependent upon the pressure differential between the pressures in the condenser and the evaporator, any change in load conditions will affect the operation of the system. In the case of refrigerators and freezers, the changes in operating

conditions can result from changes in the room ambient temperature, which affects the heat dissipation from the condenser, as well as the internal conditions, which may be determined by the opening and closing of the door and the addition of warm items to affect the load on the evaporator. Furthermore, because the system must operate on a cyclic basis to maintain reserve capacity for extreme conditions, a thermostat inside the refrigerator causes the compressor to cycle on and off, and when the compressor is off, the pressure tends to equalize throughout the system, resulting in the elimination of liquid refrigerant in the capillary tube, which then becomes entirely filled with gas. The result of these changes in operating condition is that the refrigeration system is often operating under conditions other than optimum with regard to the temperatures and pressures in the condenser and the evaporator, causing a loss of energy efficiency in the system.

Some of these effects can be minimized in various ways. For example, to minimize the formation of flash gas in the capillary tube, which would tend to reduce the capacity of the system, the tube is usually soldered or otherwise placed in heat transfer relationship with the return line from the evaporator to the compressor. Because the common optimum conditions are such where the system operates at say a fifty percent duty cycle, the capillary tube is usually sized "loose" or with a reduced restriction which allows fast flooding of the evaporator during start-up and fast equalization of suction and discharge pressure during the OFF portion of the cycle.

The fast flooding of the evaporator allows the system to quickly reach a high running efficiency, thereby reducing the total compressor run time for the ON cycle. Once the evaporator is flooded, however, this type of system tends to allow gas to enter the capillary tube and pass directly into the evaporator. When gas passes from the condenser to the evaporator, it never goes through the phase change to a liquid and back to gas that is necessary to produce effective cooling in the evaporator. Not only does this load the compressor with an increased mass flow that does not refrigerate, but it also transports heat into the evaporator, to thereby reduce the efficiency of the system. When the compressor is turned off at the end of the run cycle, the pressure equalizes between the condenser and the evaporator across the capillary tube relatively quickly, and this allows hot gas and liquid to pass into the evaporator. This adds heat to the evaporator and decreases overall system efficiency. The fast equalization, however, allows a lower cost, split phase compressor motor, with its relatively low starting torque, to restart after a short OFF cycle.

On the other hand, if the system uses a "tight" or more restrictive capillary tube, the system will tend to have a slightly greater efficiency during steady state run conditions, but the evaporator floods so slowly during start-up that the advantage in efficiency may be lost over the entire run cycle. Furthermore, equalization may take so long that the compressor may have starting difficulties with a short OFF cycle because the low starting torque is unable to overcome the remaining back pressure in the condenser.

In larger refrigeration systems, these problems are overcome by using a controlled expansion valve as the restriction instead of the capillary tube. Valves of this type generally use a diaphragm or bellows operated by a refrigerant bulb that senses the temperature at some point in the system and opens or closes the valve located at the evaporator inlet to vary the amount of restriction at this point. However, valves of this type are too large and much too expensive to be substituted for a capillary tube in small refrigeration systems.

SUMMARY OF THE INVENTION

The present invention provides an improved and more efficient refrigeration system for household refrigerators and freezers using a capillary tube restriction by adding a novel subcooling flow control valve between the condenser outlet and the entrance end of the capillary tube.

The flow control valve is an internally self-contained unit which modulates the flow proportional to the amount of subcooling in the refrigerant flowing through the valve. The valve is set to close completely when the amount of subcooling is reduced below a minimum specified positive value, and will remain closed when the compressor is turned off to prevent equalization of the system and any flow of hot refrigerant into the evaporator. When the compressor starts, it must discharge into a condenser that is already at an elevated pressure because of the lack of equalization across the flow control valve. Although this pressure will have dropped below the normal operating pressure of the condenser as a result of cooling of the condenser during the OFF cycle, the compressor still requires a high starting torque motor but not one with a higher horsepower rating for run conditions. Higher starting torque can be provided by the use of a capacitor start motor. After the compressor restarts, the pressure in the condenser will rise until a subcooled liquid is present at the outlet. When the liquid at the outlet reaches the predetermined minimum specified positive subcooling value, the flow control valve will begin to open and allow refrigerant to flow to the capillary tube, and hence into the evaporator. The flow control valve

provides increased flow as the amount of subcooling increases, and such increased flow will allow desirable flooding of the evaporator.

In this system, the capillary tube is sized as a significantly looser or less restrictive tube, and the pressure drop will be less than normal, with the rest of the drop taking place across the flow control valve. Thus, the pressure drop across the capillary tube will remain proportional to the mass flow rate of the refrigerant, while the pressure drop across the flow control valve will be inversely proportional to the mass flow rate, since the valve opens more with increased mass flow which tends to be proportional to the amount of subcooling of the refrigerant at the outlet of the condenser. Since the flow control valve will close before the amount of subcooling at the condenser outlet drops below the minimum specified value, at no time during the cycle of operation of the system will gas enter the capillary tube.

The flow control valve is a self-contained unit which is responsive to the subcooling of the refrigerant actually flowing through the valve. According to the preferred embodiment of the valve, the housing has an inlet connected to the outlet of the condenser and an outlet connected to the inlet end of the capillary tube, leading in turn to the evaporator, and this housing defines a first chamber between the inlet and the outlet. A movable wall member in the form of a sealed bellows is mounted in this first chamber between the inlet and outlet. The portion or end adjacent the inlet is fixed with respect to the housing, while the opposite or movable portion or end carries a valve element. A valve seat is mounted on the housing adjacent the outlet and is engageable by the valve element to seal and prevent any flow of refrigerant from the inlet to the outlet when the valve is fully closed. The interior of the bellows defines a second chamber which is filled with a refrigerant in a saturated state, and the refrigerant may be either the same as that in the system or a fluid which has a greater saturation pressure than that of the refrigerant in the system. To allow better response, the second chamber includes a tubular portion extending back into the inlet tube and exposed to the incoming refrigerant to ensure the most effective heat transfer between the system refrigerant and that in the second chamber, so that the second refrigerant and temperature will closely track that in the first chamber.

The minimum specified subcooling value or set point must be selected to be high enough in terms of the subcooling pressure in the surrounding refrigerant in the first chamber to ensure that the valve never opens unless there is a subcooled liquid in the first chamber and always closes before any gas can enter the capillary tube. On the other hand, the set point cannot be too high or there will

be difficulty in promoting the initial flow as the valve opens after the system has started.

It has also been found that the flow control valve operates with a faster response time on both opening and closing if it is positioned near the compressor and the refrigerant return line to the compressor. The valve is placed in a vertical position with the tubing at the inlet to the valve extending for a short distance parallel to the return line to the compressor. The two tubes are placed in a heat transferring relationship by contact. This may be done by soldering the tubes together along the length of contact. This may also be done by using a spring clip which fits over the two tubes and not only holds them in contact, but also serves to conduct heat between the two tubes. It has been found that the zone of heat conducting contact should be as close to both the compressor and the valve body as possible.

It has been found that sometimes the valve reopens after it has initially closed when the compressor has stopped and that this is caused by the evaporation of liquid refrigerant in the valve body cooling the valve to a temperature below the set point below which the valve will open. With the present valve, this cooling may result from the volume of refrigerant on the outlet side of the valve at the entrance to the capillary tube. This volume can be substantially eliminated either by placing a filler plug within the valve housing at the outlet side of the valve orifice or by reshaping the valve housing itself to reduce this space. The resulting valve does not have a sufficient volume of refrigerant at this point to cause enough cooling upon evaporation to cool the valve and the valve capsule below the set point where it will begin to reopen, and the valve will therefore remain closed until the compressor restarts.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic representation of a refrigeration system incorporating a flow control valve constructed according to the present invention;

FIG. 2 is a cross-sectional view of one preferred flow control valve constructed according to the present invention;

FIG. 3 is a cross-sectional view of another preferred flow control valve constructed according to the present invention;

FIG. 4 is a rear elevational view of a refrigerator incorporating the invention;

FIG. 5 is a fragmentary elevational view of the mounting of the flow control valve;

FIG. 5a is a cross-sectional view taken along line 5a-5a of FIG. 5;

FIG. 6 is a fragmentary elevational view similar to FIG. 5 according to another embodiment of

the invention;

FIG. 6a is a cross-sectional view taken along line 6a-6a of FIG. 6; and

FIG. 7 is an enlarged vertical cross-sectional view of modified flow control valve.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings in greater detail, FIG. 1 is a schematic illustration of a vapor compression refrigeration system 10 which is typically used in the household refrigerator or freezer. The system 10 includes an electric motor-driven compressor 12, preferably of the hermetic type, having an output connected to a condenser 14, and an evaporator 16 which is mounted inside of an insulated compartment 22 and the return from the evaporator 16 is connected back to the inlet of the compressor 12. This system is a closed recirculating system filled with a suitable refrigerant such as R12 and, to provide the necessary flow restriction between the condenser 14 and the evaporator 16, typically a capillary tube 18 is used as the expansion controlling device. While not shown in FIG. 1, typically the capillary tube 18, which is carefully sized to a given internal diameter and length, is connected in heat conducting contact with the line between the compressor 12 and the condenser 14. In accordance with the present invention, a control valve 20 is connected in the line between the condenser 14 and the entrance end of capillary tube 18.

In order to maintain the compartment 22 at desired temperature, a suitable thermostat 19 is provided to operate responsive to a sensing bulb 21 placed within the compartment 22 to sense its temperature. The thermostat 19 operates through electrical contacts which connect or disconnect the electrical supply from supply lines 23 to the electric motor driving the compressor 12. Thus, when the temperature sensed by the bulb 21 rises to a predetermined level as the result of heat influx into the compartment 22, the contacts in thermostat 19 will close to energize the compressor 12 for a length of time until the compartment 22 drops to a lower temperature, which allows the thermostat 19 and compressor 12 to cycle off until the temperature again rises to the predetermined level.

It will be understood that the length of time that the compressor 12 is running, the duty cycle, depends upon the ambient temperature surrounding the compartment 22, and the other components of the system, as well as other factors such as the thermal mass inside the compartment 22 and the number of times any access door is opened and closed to allow admission of the warmer external air. Thus, under most conditions, the system is

sized so that the compressor will have a duty cycle or run time of approximately fifty percent, but this can rise, particularly when door openings and closings occur often or there is a high ambient temperature. Likewise, if the refrigerator or freezer is placed where the ambient temperature is low, the duty cycle may be much lower.

One embodiment of the control valve 20 is shown schematically in FIG. 2 in longitudinal cross section. The valve 20 includes a short tubular valve housing 26 having an inlet fitting 28 welded or soldered to one end and defining a reduced diameter inlet opening 29 which is connected to the tubing from the condenser 14. At the other end is an outlet fitting 30 which may be similar to inlet fitting 28 and has a reduced outlet opening 31 which is, in turn, connected by a suitable fitting to the inlet end of the capillary tube 18.

The internal mechanism for the control valve 20 is shown in generally schematic arrangement, and includes an inlet plate 32 extending across the inlet side of the housing 26 and having a plurality of inlet openings 33 extending therethrough and providing sufficient area to allow free flow of the refrigerant from the inlet fitting 28 into the interior chamber 36 of housing 26. At the other end, the chamber 36 is closed off by an outlet plate 34 extending across the housing 26 in sealing relation and defining a valve seat 35 at its central opening in coaxial alignment with the inlet fitting 28 and the outlet fitting 30.

Thus, a first chamber 36 is defined by the valve housing 26 and the two plates 32 and 34, and the operating valve mechanism is located in this chamber. A boss 38 is formed on the side of inlet plate 32 within chamber 36, and serves as a seat for one end of an elongated bellows 40, whose other end is closed off by a base 43 of valve member 42, which in turn has a tip 46 adapted to engage the valve seat 35. The bellows 40 is designed to allow free longitudinal expansion so that the valve member 42 can move axially within the chamber 36 in a direction toward and away from the valve seat 35 carried on outlet plate 34. Thus, the bellows 40 defines within itself a second chamber 44 which is completely sealed from the first chamber 36, and is filled with a calibrated charge of a suitable refrigerant, which may be either the same refrigerant as is used in the system, such as R12, or one having a higher vapor pressure at the same temperature under saturated conditions, such as R500. The amount of this charge is calibrated to ensure that the valve is completely closed as long as the conditions in the first chamber are such that the amount of subcooling of the system refrigerant is below a predetermined minimum value or set point. Only when the subcooling exceeds the set point does the valve open to allow subcooled

liquid refrigerant to enter the capillary.

It should be noted that a tubular portion 48 projects from the boss 38 and is engageable by the valve member base 43 under extremely low temperature conditions to limit the movement of the valve member 42 away from the outlet plate 34. An extension tube 49 is mounted within the tubular portion 48 and extends back through the inlet opening 29, where it is sealed and, therefore, made a part of the second chamber 44. The extension tube 49, by extending back through the inlet, is in thermal transfer contact with the incoming refrigerant to ensure that the temperature of the refrigerant within the second chamber 44 will track as closely as possible the temperature of the incoming system refrigerant, to ensure a minimum of delay in response time of the valve. It should also be noted that the valve member tip 46, which extends through the valve seat 35, may be configured to provide a varying orifice size with the valve seat 35 as the valve member 42 moves to different axial positions in response to pressure and temperature changes within the valve.

When the compressor 12 is off and has not been run for some time, the valve 20 is closed, with the valve member tip 46 in tight engagement with the valve seat 35 to positively prevent any flow of refrigerant from the inlet to the outlet, and hence from the condenser to the evaporator. When the compressor is started after an OFF cycle, it pumps residual refrigerant out of the evaporator and into the condenser to cause an increase in pressure within the condenser. Since the refrigerant at the outlet of the condenser is already at a relatively cool temperature, the increase in pressure which is reflected throughout the condenser results in a sub-cooling of the refrigerant at the condenser outlet and inlet to the control valve 20. This pressure increase will act on the refrigerant within the chamber 44, which will be retained at the same low subcooling temperature as the incoming refrigerant, causing the volume within the chamber 44 to decrease. This will cause the bellows 40 to shrink and move the valve member 42 toward the inlet so that the valve member tip 46 moves away from the valve seat 35 and the valve opens to allow refrigerant to begin to flow into the capillary, and hence to the evaporator. When the compressor initially starts, the opening of the valve member 42 will tend to be somewhat gradual, and there will be a substantial pressure drop across the valve so that only a portion of the total pressure drop between the condenser and evaporator will occur across the capillary tube 18. As the valve member 42 moves farther away from valve seat 35, the resultant drop in restriction will decrease the pressure drop across the control valve 20 and increase the pressure drop across the capillary tube 18, and the

total mass flow of refrigerant will increase. In cases where the evaporator may have warmed up to a temperature substantially above the normal operating temperature, as would be the case in a frost-free refrigerator or freezer after a defrost cycle in which the evaporator had been additionally heated by an electric defrost heater, the rate of flow of refrigerant will be at a maximum and the valve 20 will be at a substantially wide open position, so that substantially all of the pressure drop takes place across the capillary tube 18, and the capillary tube must be sized to allow this flow under these conditions.

As the compressor continues running during the ON cycle, the refrigerated compartment 22 will continue to cool and the temperature of the evaporator 16 will likewise drop. Thus, there is a drop in the total mass flow of refrigerant and the subcooling at the outlet of the condenser 14 will decrease and the valve member 42 tend to move closer to a closed condition. However, the valve will remain open as long as the subcooling condition exists at the condenser outlet.

When the compressor 12 stops for any reason, such as by operation of the thermostat 19 detecting a minimum temperature in the chamber 22, there is no longer any flow of refrigerant into the condenser 14 and the pressure at the outlet will tend to rise as liquid refrigerant continues the flow through the valve 20 and into the capillary tube 18. However, as soon as the pressure reaches a set point which is still within the subcooling range, the valve member 42 will close so that the tip 46 seals off the valve seat 35 to prevent any further flow of refrigerant from the condenser to the evaporator. This ensures that no vapor will enter the evaporator, and prevents heat from being transferred from the condenser to the evaporator as long as the compressor is on the OFF cycle. Since vapor entering the evaporator as a result of the refrigerant's being above the subcooling threshold would decrease the efficiency of the system, the prevention of refrigerant flow during the OFF cycle prevents the heating of the evaporator, and hence the compartment 22, that would otherwise occur if the valve 20 were not present.

Although the pressure within the condenser will continue to drop from cooling of the refrigerant during the compressor OFF cycle, there will still tend to be a substantial back pressure at the discharge side of the compressor when it restarts at the beginning of the next ON cycle, and this back pressure will require substantially higher starting torque from the compressor motor than would otherwise be required if the pressure were allowed to equalize between the condenser and evaporator. This can be overcome by using a high starting torque electric motor for the compressor, and it has

been found that the use of capacitor start motors for the compressor will easily provide sufficient starting torque that restarting of the compressor will not be a problem.

After the compressor restarts, because of the pressure differential between the condenser and evaporator as a result of valve 20 being closed, running conditions are more quickly re-established than if the pressure had equalized. The evaporator is reflooded more quickly, thus resulting in a decrease of the run time of the compressor for a given amount of cooling during the ON cycle.

Another embodiment of the control valve is shown at 58 in FIG. 3, and it will be understood that this valve is located in the system shown in FIG. 1 in the same position as control valve 20. This control valve includes a housing 60 comprising cup-shaped inlet and outlet members 61 and 62, each having peripheral flanges 63 and 64. Within the housing 60 is located a transverse partition member 65, also having a peripheral flange 66 which is clamped between the flanges 63 and 64 in the form of a sandwich, which may then be brazed and welded around its periphery to provide a unitized sealed housing 60. The inlet member 61 is provided with a central inlet fitting 67 which is connected to the condenser 14, while the lower or outlet member 62 is provided with an outlet fitting 68, which in turn is connected to the capillary tube 18. Then, as control valve 58 is located in the system, it is preferably positioned so that the inlet fitting 67 is uppermost and the axial alignment between the fittings 67 and 68 is substantially vertical. The valve should be located at a generally low point in the system to ensure positive liquid flow from the condenser 14 into the inlet fitting 67.

The partition member 65 separates the interior of housing 60 into an inlet chamber 71 between the inlet member 61 and partition 65 and an outlet chamber 72 between the partition 65 and the outlet member 62. Within the inlet chamber 71, a support plate 74 is positioned a spaced distance from the partition 65 and has an outer peripheral edge 76 which is secured by welding or brazing to the flange 66 and partition 65 within the inlet chamber 71. The support plate 74 has a plurality of openings 77 therein to ensure free fluid communication within the chamber 71 on both sides of the support plate 74.

Between support plate 74 and partition 65 is located a movable wall member in the form of upper and lower diaphragm members 81 and 82, which are sealed together around the edges 83 and define a chamber 80 between them. The upper diaphragm member 81 is stationary with respect to the support plate 74, while the lower or movable diaphragm or wall member 82 carries on its lower side a cup 84 secured thereto by welding or braz-

ing, and carrying a valve seal 86 which may be formed of a suitable resilient material such as polytetrafluoroethylene or a suitable rubberlike elastic material which is fully compatible with the refrigerant of the system. The valve seal 86, in turn, is adapted to make contact with the valve seat 87 formed around opening 88 extending through the partition member 65 and providing the sole communication between the inlet chamber 71 and the outlet chamber 72. If it is so desired, the cup 84 or other members can be configured to engage the partition 65 to limit travel of the cup 84 and seal 86 against the valve seat 87 to minimize the effects of cold flow or set on the material forming the seal 86.

To secure the upper diaphragm member 81 in position, it is secured to a flange 91 on a fitting 90, with the flange 91 also being held in position against the lower side of support plate 74 by a bead 92 formed on the fitting 90 above the support plate 94. The upper end of fitting 90 is formed with an open end 94, where it is sealingly secured to the end of a tube 95 which extends upwardly through the inlet fitting 67. At its lower end, tube 95 makes a sealing fit against an opening 96 in the upper diaphragm member 81, so that the interiors of tube 95 and chamber 80 are in full fluid communication but sealed from the inlet and outlet chambers 71 and 72. Thus, the chamber 80 is filled with a second refrigerant in a saturated condition in the same manner as second chamber 44 of control valve 20.

It will thus be seen that the valve of FIG. 3 operates in the same manner as the valve of FIG. 2, in that as long as the conditions of the fluid within the inlet chamber 71 and inlet fitting 67 are at temperatures and pressures above a subcooling level, the valve seal 86 will be in tight engagement with the valve seat 87 to prevent fluid communication between the inlet and outlet chambers 71 and 72, and hence prevent any flow through the valve. As soon as a subcooling condition exists when the system is in operation, such subcooling will reduce the temperature and/or increase the pressure within the inlet chamber 71, and hence the second chamber 80, and the result will allow the valve seal 86 to move away from the valve seat 87 so that refrigerant will flow through the valve in the same manner as described above.

FIG. 4 shows the back of a refrigerator 110 incorporating the present invention. Refrigerator 110 includes a cabinet 111 having a back panel 112 having an opening at the lower end exposing the machine compartment 114 within which is mounted a compressor 116 and other components of the refrigeration system. Compressor 116 includes an outlet line 118 which in turn connects to a vertical line 119 extending upwardly along the

back panel 112 to the upper end of a serpentine tubing condenser 121 which is suitably mounted a spaced distance away from the back panel 112 to allow adequate air circulation and heat transfer.

At the bottom of the condenser 121, the refrigerant is conducted through a connecting tube 123 to a dryer cartridge 122 and the outlet from the dryer cartridge 122 is connected through a line 126 to a flow control valve 124 which is preferably constructed as shown hereafter. The outlet of the flow control valve 124 is connected to a capillary tube 128 which extends upwardly to the evaporator 129 mounted within the cabinet 111 and generally extends in heat conducting relationship with the return line 131 which extends from the outlet of the evaporator 129 back to the compressor 116. As shown in FIGS. 5 and 6, a portion 134 of line 126 between the dryer and the flow control valve extends parallel to and in abutting contact with a portion 136 of the return line 131 close to the compressor 116. It has been found that by allowing heat transfer between the portions 134 and 136, response of the flow control valve 124 is improved by the heat transfer on both the starting and the stopping of the compressor. Thus, when the compressor is turned off, the hot compressor conducts heat back through the return line to tend to warm up the flow control valve and thus, bias it to a closed position. On the other hand, when the compressor is started, the immediate pressure drop in the return line causes the temperature to drop, thereby tending to cool the flow control valve by cooling the refrigerant entering the valve so that it will open more quickly and allow flow through the entire system with a minimum of delay after the compressor starts.

A modified flow control valve 124 is shown in detail in FIG. 7 and is generally similar to the valve shown in FIG. 3. The valve includes upper and lower housing members 143 and 146 in the form of opposed cup-shaped members having flanges 144 and 147, respectively, which are secured together around the edges on either side of a flange 152 on a center partition member 151 extending transversely across the interior of the housings 143 and 146 to divide the interior into an upper chamber 153 and lower chamber 154. At the center of the upper housing 143 is a fitting to receive the line 126 from the dryer cartridge 122 while the lower housing 146 has a fitting to receive an outlet tube shown at 148 to which is connected the capillary tube 128.

Within the upper chamber 153 is located a support member or plate 156 extending transversely across the chamber a spaced distance from the partition member 151 to which it is rigidly secured at a peripheral flange 157. The support member 156 includes a number of openings 158 to allow

refrigerant to flow freely through the support member to a point adjacent the partition member 151. Within the space between support member 156 and partition member 151 is located an assembly comprising upper and lower diaphragm members 161 and 162 which form a sealed chamber 160. The upper diaphragm 161 is rigidly secured to a fitting 164 which in turn is rigidly mounted on the support member 156 and connected to a tube 166 which forms part of chamber 160 and extends upward into the inlet line 126 for a spaced distance to allow heat transfer between the fluids within the chamber 153 and within the sealed chamber 160. The lower diaphragm member 162 carries on its central portion a rigidly secured cup 168 which carries an elastomeric valve seal 169 adapted to make valving contact with a valve seat opening 171 formed at the center of the partition member 151.

While the chambers 153 and 154 contain the refrigerant filling charge of the system, the chamber 160 including the interior of tube 166 is sealed off from the system refrigerant and filled with a saturated charge of a refrigerant that may be the same as the system refrigerant or be one having a higher vapor pressure at the same temperature under saturated conditions. The volume of the saturated refrigerant within the chamber 160 is carefully calibrated to insure the opening and closing of the valve by movement of the lower diaphragm member 162 and hence, the valve seal 167 toward and away from the valve seat 171. Thus, the charge is sufficient that the valve is normally closed until the pressure and temperature within the chamber 153 and hence chamber 160 reaches a set point below the subcooling conditions to ensure that the chamber 153 is filled with a subcooled liquid from the condenser. Under these conditions of subcooling, the refrigerant within the chamber 160 will be compressed to allow the lower diaphragm member 162 to move upwards to move the valve seal 169 away from seat 171. When this is done, the valve is opened and refrigerant can now pass into the capillary 128 and evaporator 129 to cool the cabinet 111. Thus, as long as a compressor 116 is running, the flow control valve 124 operates in modulating manner to insure that only a subcooled liquid is allowed to enter the capillary tube 128. Thus, as the amount of subcooling among the chamber 153 increases, the valve seal 169 will move farther away from valve seat 171 to allow increased fluid flow into the capillary, while a decrease in the amount of subcooling still below the set point causes the valve seal 169 to move closer to the valve seat 171 to provide additional throttling and decreased flow into the capillary tube.

When the compressor 116 is turned off as a result of the control signal from the thermostat indicating that the chamber of the cabinet 111 is

now at its lowest temperature, there is no further flow into the condenser 121 with the result that the subcooling in the chamber 153 is reduced and eventually result in a condition where vapor is present at the outlet of the condenser. In the absence of the flow control valve 124, that vapor would then enter the capillary and hence the evaporator 129 causing a heating effect that would counteract some of the earlier cooling. To prevent that, the flow control valve closes once the subcooling is reduced below the set point, and the valve seal 169 moves into sealing engagement with the valve seat 171 to prevent any flow of refrigerant from the condenser into the capillary tube. By maintaining the valve closed while the compressor is off, there is no heat transfer into the evaporator resulting from gas flow through the capillary and there tends to be a residual amount of liquid in the condenser so that a subcooling condition can be re-established fairly quickly after compressor restart to allow the flow control valve to open. However, it is important that the valve not reopen while the compressor is on the off cycle. Under certain conditions, it has been found that the valve may reopen with a consequent loss of efficiency and it is believed that one of the reasons for this is the presence of a large amount of refrigerant in liquid form in the chamber 154. It has been found that after the compressor is stopped and the valve closes, the liquid refrigerant in chamber 154 gradually vaporizes as a result of additional flow through the capillary tube from the existing pressure differential. The change of phase of this refrigerant in chamber 154 turning into gas results in a cooling that tends to absorb heat from the other side of the partition member 151 to the point where the conditions in the diaphragm chamber 160 result in sufficient subcooling of that refrigerant that the valve may reopen. Once that happens on the off cycle, the valve will not reclose and the flow control valve fails to prevent heat transfer to the evaporator.

To overcome this problem, it has been found that reopening of the valve can be prevented effectively by reducing the volume of the lower chamber 154 to an absolute minimum. This may be done by substantially filling the chamber with a plug 173 which may be formed of any suitable plastic material such as nylon, and by shortening the length of the outlet tube 148 to bring the entrance to the capillary tube 128 as close to the valve seat opening 171 as possible. Of course, the volume may also be reduced by reshaping the lower housing 146 to minimize the volume of the chamber.

To further prevent reopening of the valve when the compressor is off, as well as to increase the response time for the valve to reopen after the compressor is restarted, it has been found desir-

able to mount the flow control valve 124 in a position adjacent the compressor 116 and actually place the inlet line to the flow control valve 126 in heat exchange contact with the compressor return line 131 from the evaporator. Since the flow control valve 124 should be mounted in a vertical position with the inlet line 126 and outlet tube 148 arranged along a vertical axis, the upper end of the line 126 is preferably bent at an angle to extend for a short distance to be parallel to the return line 131 as close to the compressor as possible so that the length of the return line 131 between the line 126 and the compressor itself is at a minimum. To aid in the heat conducting contact, the tubes are held in abutting contact by means of a metal clip as shown in FIG. 5. The metal clip is preferably made of a flat band of spring steel 176 extending around the tubes and in abutting contact so that heat transfer is obtained between the two tubes not only by their abutting contact but also through the clip itself which extends around a substantial portion of the periphery of each of the tubes.

An alternative arrangement is shown in FIG. 6 wherein the absence of a clip 176, a bead of solder 179 is secured to both of the tubes not only to hold them in abutting contact but also to provide heat transfer through the solder bead itself.

By providing heat transfer between the return line 131 and the line 126 leading to the flow control valve 124, improved performance of the flow control valve 124 is provided on both starting and stopping of the compressor 116. When the compressor is turned off, cooling of the flow control valve 124 and the chamber 160 is further prevented by heat transfer from the compressor, which is relatively hot, back through the return line 131 to the inlet tube 126. Since the tube 166 within the tube 126 forms an extension of the chamber 160, the line 126 tends to quickly warm up from heat transfer from the return line 131 and this in turn allows heat to be added to the refrigerant within the chamber 160 and tube 166 to ensure that the valve 124 remains positively closed as long as the compressor is off. When the compressor is restarted, the return line 131 tends to cool at once as the pressure within it is reduced because of the suction in the compressor. This cooling in the return line 131 thus absorbs heat from the line 126 causing further cooling in the chamber 160 and tube 166 to insure rapid opening of the valve as a subcooling condition is created with the inflow of refrigerant from the condenser 121.

As a result of these provisions, the flow control valve 124 operates more rapidly and in a more positive manner not only by opening and closing promptly with the starting and stopping of the compressor, but also in avoiding any possible reopening during the off cycle which would result in a loss

of efficiency for the system.

Claims

- 5 1. A refrigerated cabinet comprising a compartment, a compressor, a condenser, an evaporator in said compartment, a capillary tube connecting said evaporator and said condenser in a closed circuit containing a first refrigerant, a thermostat responsive to the temperature in said compartment for selectively energizing said compressor to maintain the temperature in said compartment within a predetermined range, a flow control valve between said condenser and said capillary tube, said flow control valve having a housing defining a first chamber, an inlet to said first chamber connected to said condenser, an outlet from said first chamber to said capillary tube, a valve seat on said housing at said outlet, a movable wall member within said first chamber defining a second chamber, said movable wall member being secured to said housing, a valve member operable by movement of said movable wall member to move to and from said valve seat, said second chamber being filled with a predetermined saturated charge of a second refrigerant whereby said valve member is spaced from said valve seat when the subcooling of said first refrigerant in said first chamber is greater than a predetermined amount and said valve member is moved into engagement with said valve seat when the subcooling of said refrigerant in said first chamber is less than said predetermined amount, engagement of said valve member with said valve seat preventing any flow of said first refrigerant from said inlet to said outlet.
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- 35
- 40 2. A refrigerated cabinet as set forth in claim 1, wherein said movable wall member is a bellows having one portion secured to said housing and another portion secured to said valve member.
- 45
- 50 3. A refrigerated cabinet as set forth in claim 1, wherein said second refrigerant is the same as said first refrigerant.
- 55 4. A refrigerated cabinet as set forth in claim 1, wherein said second refrigerant has a higher vapor pressure than that of said first refrigerant at the same temperature.
5. A refrigerated cabinet comprising a compartment, a compressor, a condenser, an evaporator in said compartment, a capillary tube connecting said condenser and said evaporator in

a closed circuit containing a first refrigerant, said circuit including a return line from said evaporator to said compressor, a thermostat responsive to the temperature in said compartment for selectively energizing said compressor to maintain the temperature in said compartment within a predetermined range, a subcooling flow control valve between said condenser and said capillary tube, said flow control valve having a housing, an inlet tube to said housing connected to said condenser, an outlet tube from said housing to said capillary tube, said flow control valve being operable when the subcooling of the refrigerant at said inlet tube is greater than a predetermined amount to open said valve and permit flow of refrigerant from said condenser into said capillary tube and when the subcooling of said refrigerant in said first chamber is less than said predetermined amount to close said valve and prevent flow of refrigerant into said capillary tube, said flow control valve housing being positioned on said cabinet adjacent said compressor with said inlet tube in heat conducting contact with said return line.

6. A refrigerated cabinet as set forth in claim 5, including heat conducting means secured to both said tube and said return line.

7. A refrigerated cabinet as set forth in claim 6, wherein said heat conducting means is a metal clip extending over said tube and said return line.

8. A refrigerated cabinet as set forth in claim 6, wherein said heat conducting means is a soldered joint.

9. A refrigerated cabinet comprising a compartment, a compressor, a condenser, an evaporator in said compartment, a capillary tube having an outlet connected to said evaporator and an inlet connected to said condenser in a closed circuit containing a first refrigerant, a thermostat responsive to the temperature in said compartment for selectively energizing said compressor to maintain the temperature in said compartment within a predetermined range, a flow control valve between said condenser and said inlet to said capillary tube, said flow control valve having a housing defining a first chamber, an inlet to said first chamber connected to said condenser, an outlet from said first chamber to said capillary tube, a valve seat on said housing at said outlet, a movable wall member within said first chamber defining a second chamber, said movable wall

member being secured to said housing, a valve member operable by movement of said movable wall member to move to and from said valve seat, said second chamber being filled with a predetermined saturated charge of a second refrigerant whereby said valve member is spaced from said valve seat when the subcooling of said first refrigerant in said first chamber is greater than a predetermined amount and said valve member is moved into engagement with said valve seat when the subcooling of said refrigerant in said first chamber is less than said predetermined amount, engagement of said valve member with said valve seat preventing any flow of said first refrigerant from said inlet to said outlet, the volume of refrigerant in the space between said valve seat and said capillary tube inlet being sufficiently small that evaporation of said refrigerant volume will not cool said second chamber to permit said valve member to move away from said valve seat and reopen the closed valve.

10. A refrigerated cabinet as set forth in claim 9, wherein said space between said valve seat and said capillary tube inlet defines a third chamber and said third chamber is substantially filled by an inert member.

11. A refrigerated cabinet as set forth in claim 10, wherein said inert member is a plastic plug.

12. A refrigerated cabinet as set forth in claim 11, wherein said plastic is nylon.

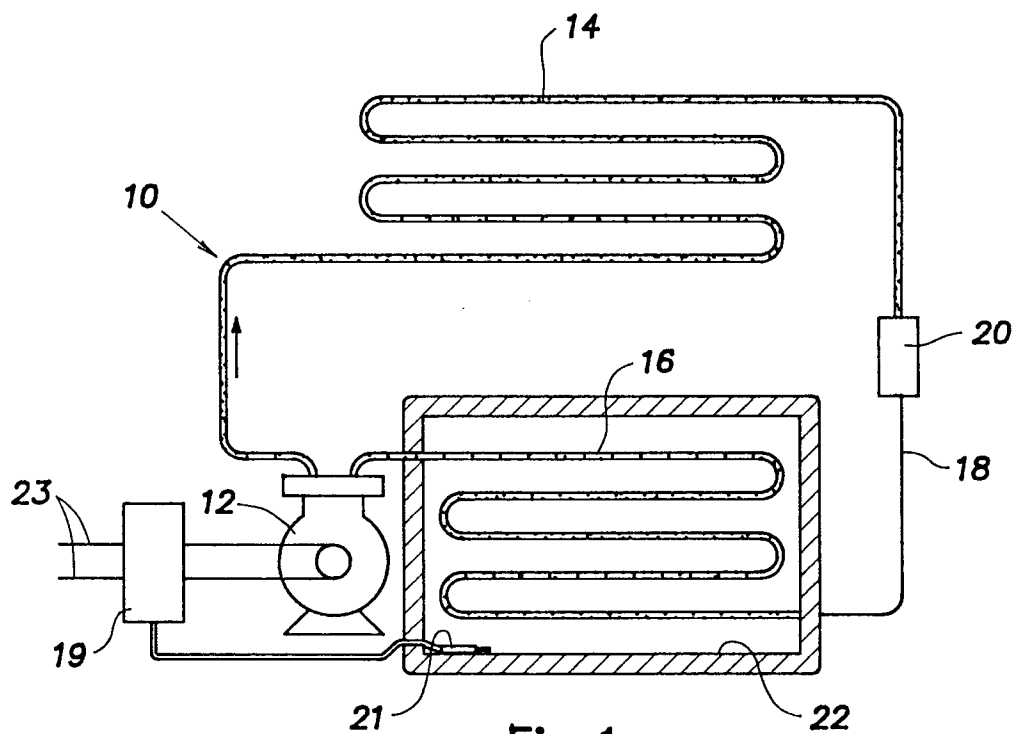


Fig. 1

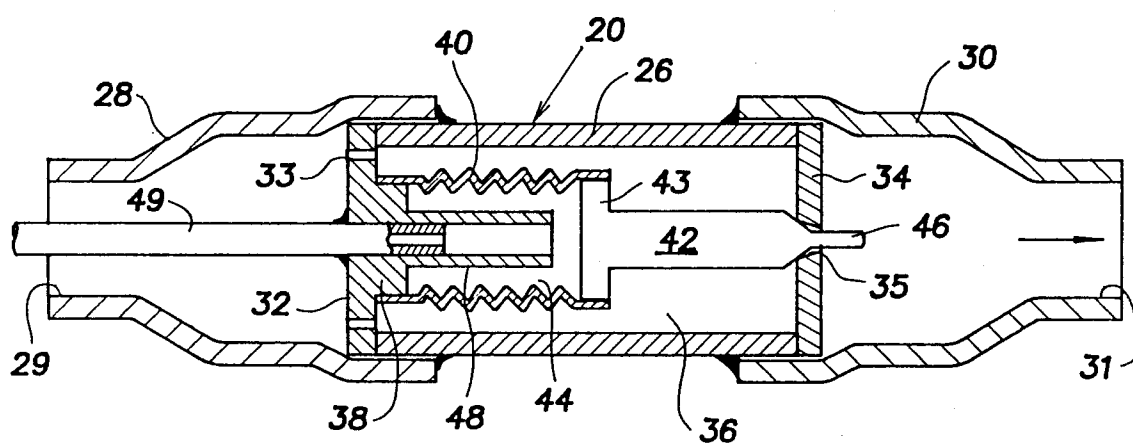


Fig. 2

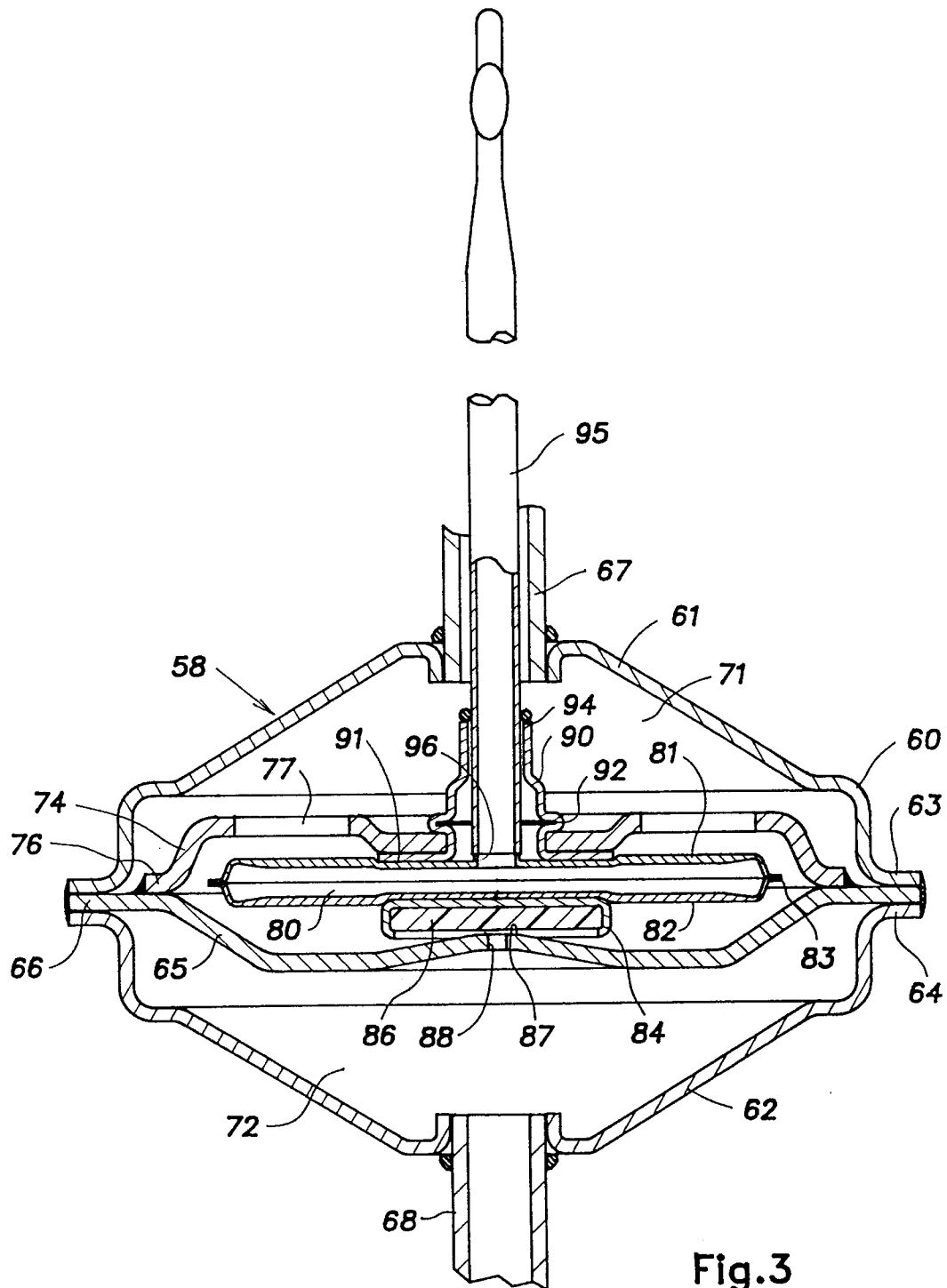
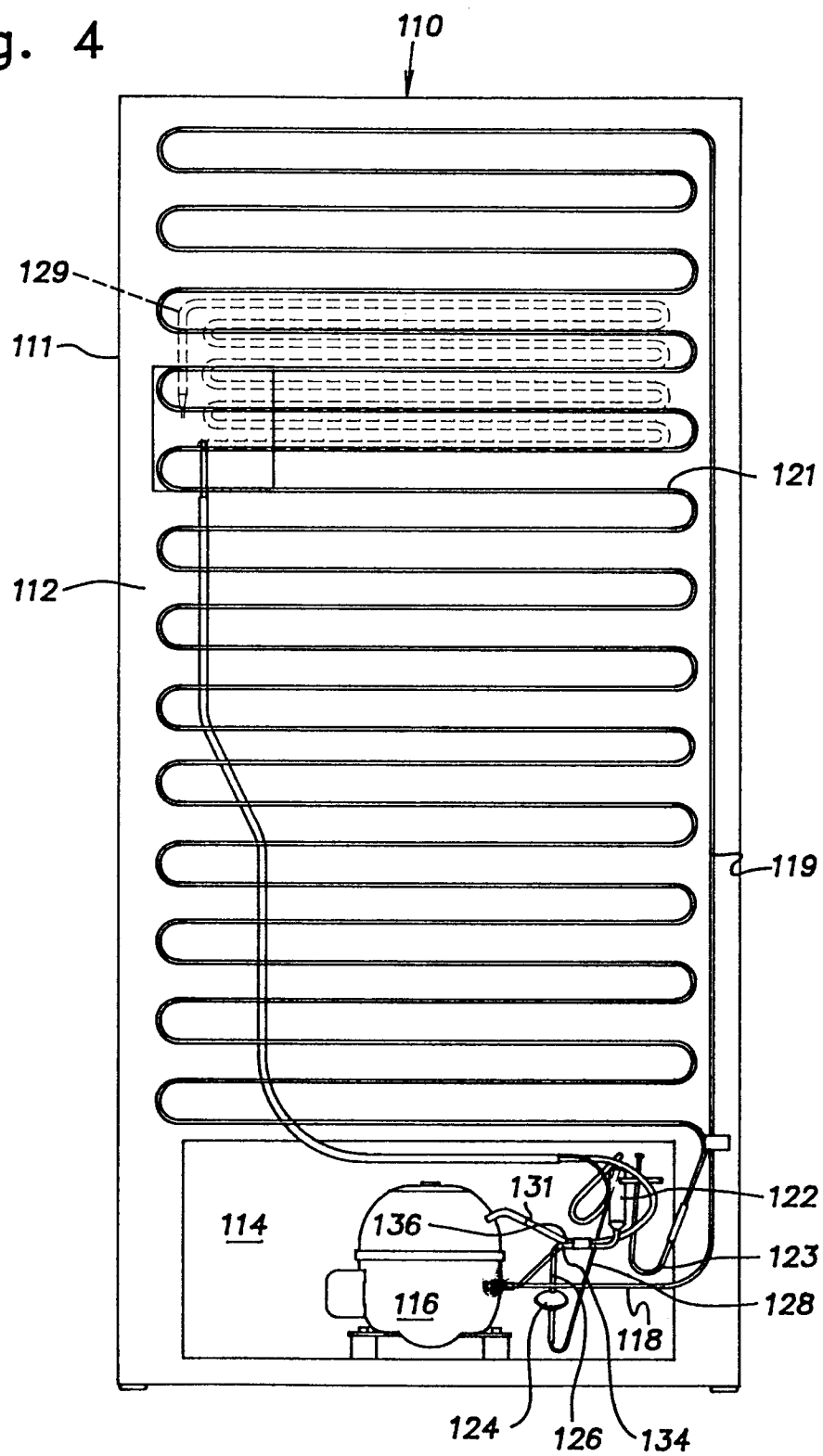
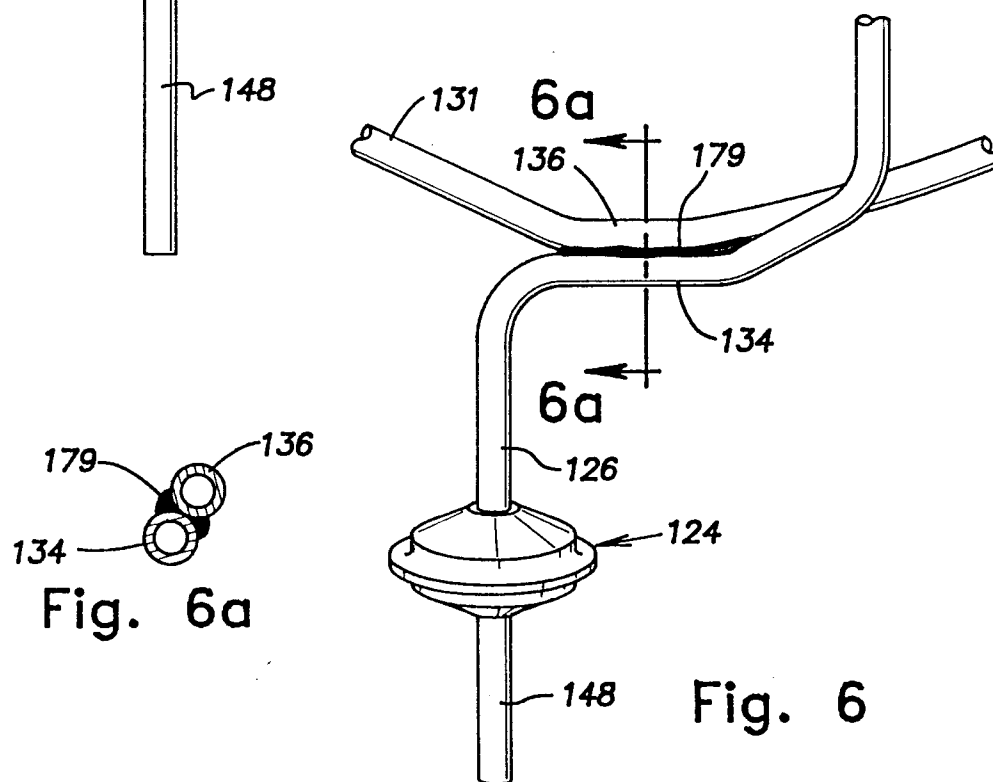
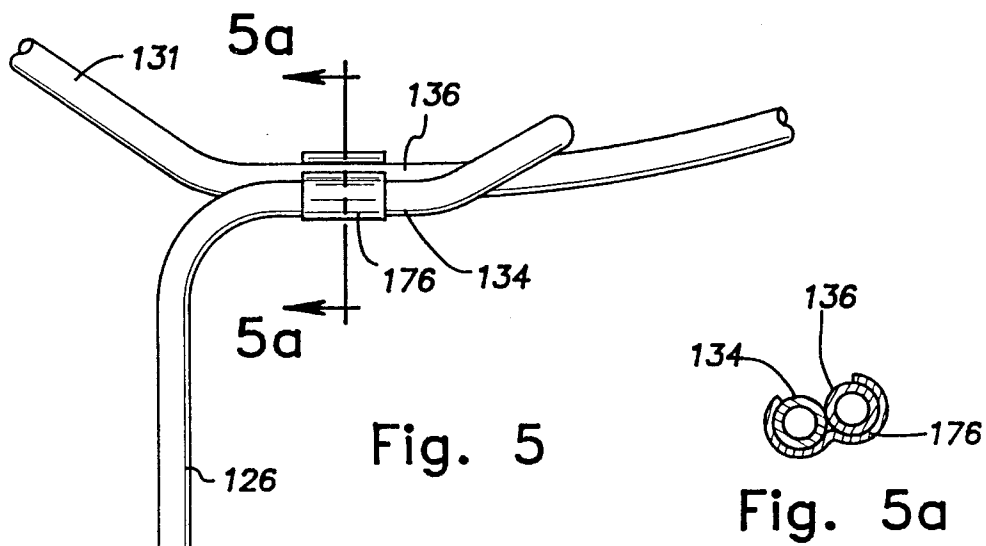


Fig. 4





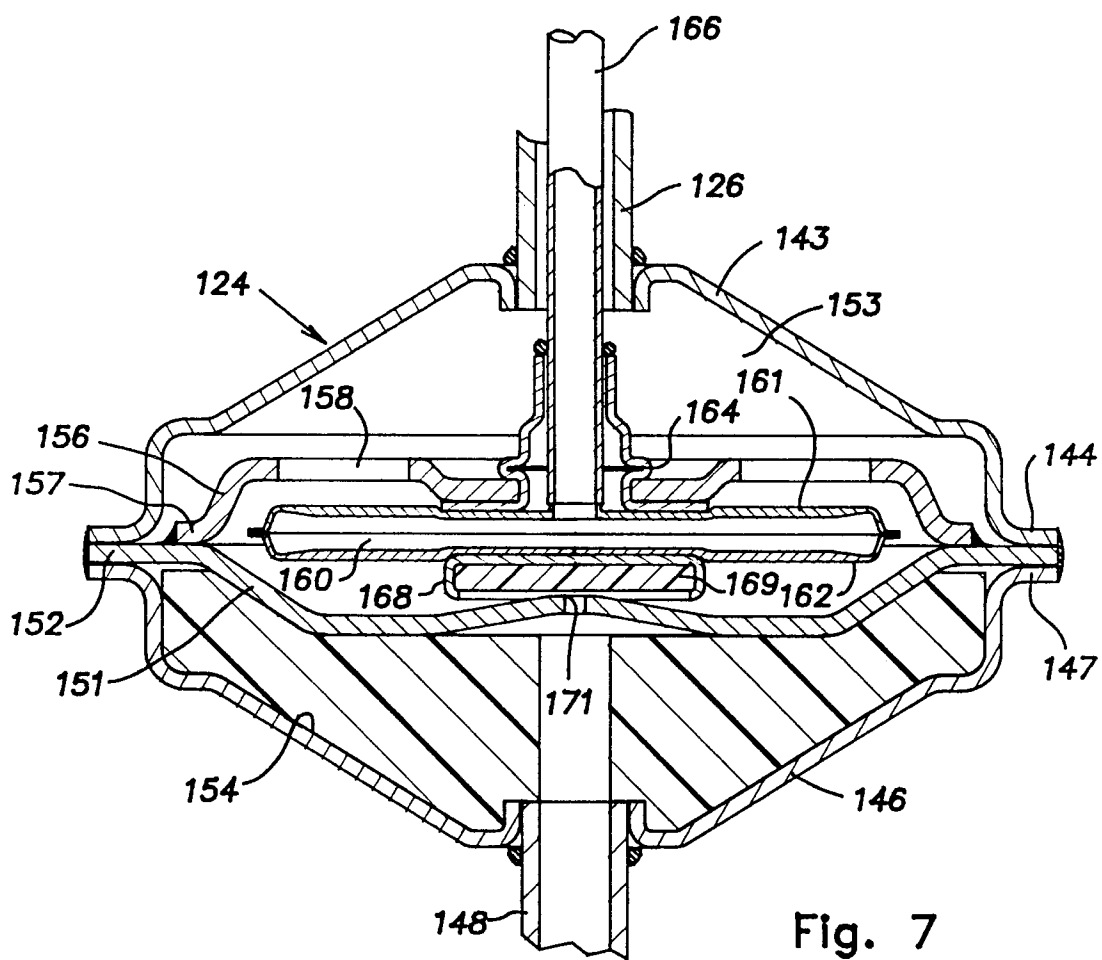


Fig. 7



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number

EP 92 10 4263

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
Y	EP-A-0 272 826 (SANDEN)	1-4	F25B41/04
A	* the whole document *	5,9	F25B49/02

Y	GB-A-2 121 942 (TOKYO SHIBAURA DENKI)	1-4	
A	* page 1, line 64 - page 2, line 115; figures *	5,9	

A	DE-C-950 887 (DAIMLER-BENZ)		

A	CH-A-460 412 (GUSTAV F. GERDTS)		

A	US-A-4 402 455 (KOLT)		

			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			F25B G05D
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 25 JUNE 1992	Examiner BROMAN B. T.
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			