Oct. 3, 1944. F. O. URBAN 2,359,595

REFRIGERATING SYSTEM

Filed July 27, 1943

Fig. 1.

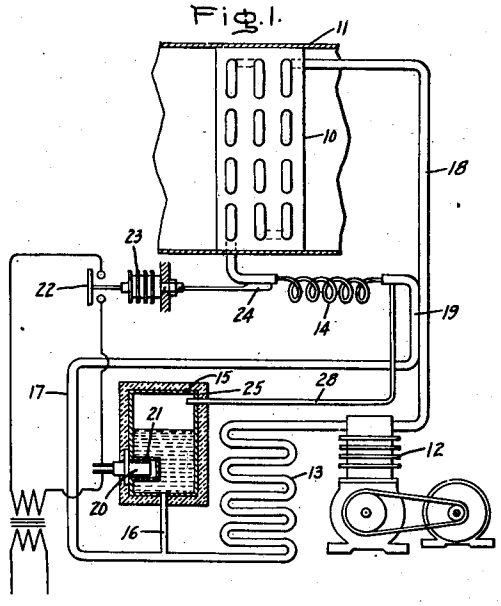


Fig. 2.

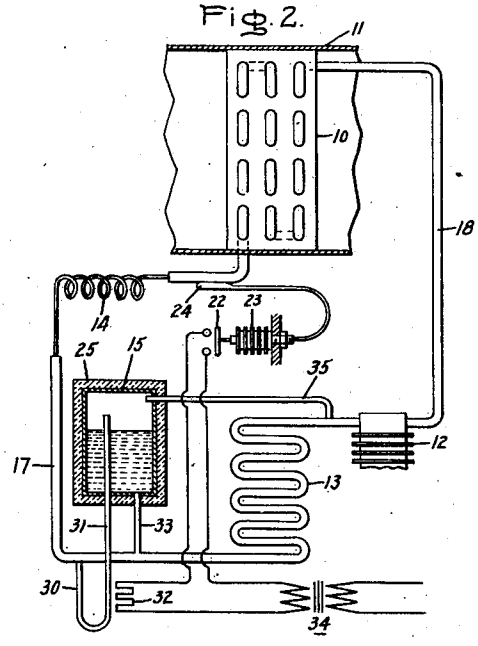
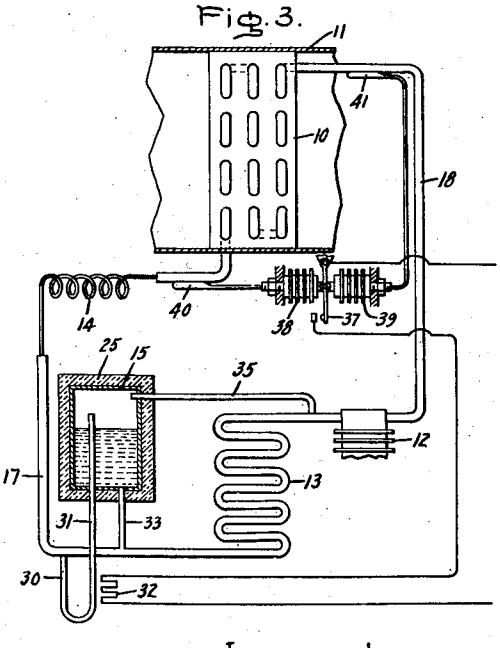


Fig. 3.



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REFRIGERATING SYSTEM

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10 Claims. (Cl. 62—3)

My invention relates to refrigerating systems and particularly to such systems which are provided with refrigerant expansion devices of the fixed restrictor or capillary tube type.

A mechanical refrigerating machine commonly comprises a condensing unit and an evaporating unit. In compression type systems, the condensing unit comprises a motor driven compressor and an air or liquid cooled condenser for liquefying the compressed refrigerant. In order to control the flow of refrigerant from the high pressure of the condensing unit to the low pressure of the evaporating unit, some form of expansion valve or device is necessary. It has been found practicable in many cases to employ a capillary tube or other device providing a fixed restriction between the condensing unit and the evaporator. Refrigerating machines equipped with capillary tubes must be designed specifically for the range of temperatures and pressures within which they are expected to be employed. The flow of refrigerant through a capillary tube decreases with a decrease in the pressure difference across the tube, and even though there is no change in the conditions surrounding the evaporator, a decrease in condensing pressure may produce an objectionable decrease in flow of refrigerant. One important factor which is involved in the determination of the range of operation of the refrigerating machine is the quantity of the charge of refrigerant employed in the system. It has been found, for example, that a refrigerating machine will produce different suction pressures when the machine is charged with different amounts of refrigerant. The charge of refrigerant placed in the system critically determines the practical range of operation of the system.

It is an object of my invention to provide a refrigerating machine employing an expansion device of the fixed restrictor type and including an improved arrangement for increasing the effective range of operation of the machine.

It is another object of my invention to provide a refrigerating machine having an expansion device of the fixed restrictor type and including an improved arrangement for varying the effective capacity of the system in accordance with the requirements of the system.

It is another object of my invention to provide an improved arrangement for controlling the operation of a refrigerating system which is provided with an expansion device of the fixed restrictor type.

Further objects and advantages of my invention will become apparent as the following description proceeds, and the features of novelty which characterize my invention will be pointed out with particularity in the claims annexed to and forming a part of this specification.

For a better understanding of my invention, reference may be had to the accompanying drawing in which Fig. 1 represents diagrammatically a refrigerating system embodying my invention, and Figs. 2 and 3 represent other embodiments of my invention.

Briefly, each of the refrigerating systems disclosed in the drawing comprises a compressor, a condenser and an evaporator connected in series to provide a normal refrigerant circuit, a capillary tube restrictor is provided in the circuit between the condenser and the evaporator to control the flow of liquid refrigerant from the high pressure side to the low pressure side of the refrigerant circuit. A refrigerant storage chamber is connected in restricted communication with the condensing unit and a control is provided which causes an interchange of liquid refrigerant between the refrigerant circuit and the chamber. The control is actuated in accordance with a predetermined condition of operation of the system, and the effective capacity of the system is varied by storing more or less liquid refrigerant in the chamber out of the path of flow of the refrigerant in the circuit.

Referring now to the drawing, the refrigeration system shown in Fig. 1 comprises an evaporator 10 arranged in an air duct 11 for cooling the air passing therethrough. Vaporized refrigerant is withdrawn from the evaporator by operation of a compressor 12, and the hot compressed refrigerant is cooled and liquefied in a condenser 13. Liquid refrigerant is then returned to the evaporator 10 under control of a capillary tube or elongated orifice 14. The refrigerant circuit including the evaporator, compressor, condenser and capillary tube will operate satisfactorily within a predetermined range of operating conditions, the limitations of satisfactory operation depending upon the quantity of refrigerant with which the circuit is charged.

I have found that the suction pressure of a refrigerating machine of the above type may be effectively controlled by varying the quantity of refrigerant in the system. As long as the system is operated so that there is no superheat at the evaporator outlet the change in refrigerant charge results in a change in both the evaporator and the condenser pressures, and by selecting the quantity of refrigerant in the circulating

system, the evaporator can be operated at any desired percentage of its maximum capacity. The effect of changing the refrigerant charge in a system such as shown in Fig. 1 is to vary the effective area of the condenser, the greater charge causing liquid refrigerant to back up into the condenser and blank off a portion of the walls of the condenser. The change in the effective condensing surface results in a change in head pressure and in the amount of liquid subcooling and the result is a corresponding change in the flow through the capillary tube.

In order to vary the effective charge in the refrigerant circuit, I provide a closed chamber or tank 15 outside the refrigerant circuit and in communication with the circuit through a restricted tube or duct 16 connecting the bottom of the chamber with the lowermost portion of the condenser. Liquid refrigerant flowing from the condenser 13 fills a liquid line indicated at 17 as a continuation of the condenser and a portion of this liquid may be cooled by heat exchange with the cold vapor withdrawn from the evaporator through the suction line indicated at 18. For this purpose portions of the lines 17 and 18 are connected in heat exchange relation at 19. The chamber 15 may be located at any suitable position where it is normally in an ambient having a temperature lower than the condensing temperature of the refrigerant in the condenser. In Fig. 1, the chamber 15 is arranged in the same ambient as the condensing unit. The tube 16 is of sufficiently small diameter to prevent the liquid refrigerant from surging. The temperature of the chamber 15 determines the pressure of the refrigerant therein, this pressure being equal to the saturation pressure of the refrigerant at the chamber temperature. As long as the temperature is below the temperature of the refrigerant in the condenser 13, the resulting pressure difference between the chamber and the condenser will cause liquid refrigerant to flow out of the refrigerant circuit through the duct 16 into the tank 15 until a state of equilibrium is established. In order to change the temperature within the chamber 15 and thereby change the pressure and the amount of refrigerant stored within the chamber, an electric heater 20 is arranged within a recess 21 in the chamber wall and is energized from a suitable source of electric current by closing a switch 22 in accordance with the temperature at the outlet of the capillary tube 14. The switch 22 is operated by a bellows 23 actuated in accordance with the pressure within a thermal bulb 24 secured in heat exchange relation with the inlet of the evaporator 10 adjacent the capillary tube 14. When the temperature falls the switch 22 is closed and the heater is energized to decrease the amount of refrigerant in the chamber 15. If desired, the chamber 15 may be provided with a covering 25 of thermal insulation to decrease the rate of change of the tank temperature with changes in the temperature of the ambient medium. The tank 15 is relatively small because a considerable change in operating conditions may be effected by relatively small changes in the amount of refrigerant charge. By selecting the proportions of the mass and of the insulation of the tank 15, the capacity of the heater 20, and the size and length of the duct 16, the time constant of the tank may be made as long as desired. The thermostatic switch 22 may be of any suitable type and may be made to be sensitive to small changes and have a low time constant, that is, a rapid response characteristic. The selection of the above design structure to provide a long time constant for the chamber and a short time constant for the thermostatic control provides inherent stability. The control bulb or feeler 24 has been shown responsive to the evaporator inlet temperature only by way of example, it being obvious that the system may be controlled in accordance with other operating conditions if desired. The control as shown in Fig. 1 would normally be employed when the evaporator 10 is maintained partially flooded. In order to prevent the accumulation of noncondensable gases in the tank 15, a highly restricted tube 28 is connected between the upper portion or vapor space of the tank 15 and a portion of the condensing unit which is normally at a pressure lower than that of the tank 15; the tube 28 has been illustrated as communicating with the liquid line 17 adjacent the inlet to the tube 14. A continuous flow of vapor through the tube 28 results; however, if the tube 28 is sufficiently restricted, the resulting loss in refrigerating efficiency may be made negligible, for example, the loss may be made only one tenth of one per cent.

The refrigerating system of Fig. 1 may, for example, be employed in a room cooler which circulates air over the evaporator 10 and which provides for circulation of withdrawn air over the condensing unit including the compresser 12, condenser 13 and tank 15. Let us assume that the withdrawn temperature is 95° F. and that the room cooler is maintaining the room air at a dry bulb temperature of 80° F. and a wet bulb temperature at 67° F. These conditions will produce a predetermined average suction pressure and an average head pressure dependent upon the particular refrigerant employed. The chamber might, for example, be somewhat over half full of liquid refrigerant and under the control of the thermostatic switch 22, the heater 20 would be furnishing heat at an average rate to maintain a predetermined temperature within the tank 15. If the weather conditions change and lower the outdoor temperature to 85° F., the head pressure will drop quickly and will reduce the flow through the capillary tube 14 and result in a drop in the suction pressure and a corresponding loss in the capacity of the system. The conditions within the room, however, will not change for some time because of the heat storage in the building and for this reason the decreased refrigerant flow causes an increase in the evaporator superheat. Momentarily, at the time of the change, there will be a flow of liquid refrigerant out of the tank but there will also be evaporation of liquid to fill the displaced volume and this will cool the small mass of liquid to a new temperature at which equilibrium will be reached, and the flow of liquid refrigerant through the duct 16 will stop. Further cooling of the tank 15 because of the new low temperature of the air circulating around the condensing unit may then reverse the flow and begin to fill the tank. However, the decrease in evaporator temperature at the bulb 24 due to the lower pressure will close the switch 22 and supply heat to the tank 15 and increase the temperature of the tank so that liquid refrigerant will be forced back into the refrigerant circuit. The additional liquid refrigerant forced into the circuit will flow back into the condenser and reduce the effective condensing surface, thereby raising the condensing temperature, and the increased amount of liquid refrigerant in the condenser also will cause great-

er subcooling of the liquid than before the change. The higher condenser pressure and the greater subcooling results in an increased flow through the capillary tube and increases the evaporator capacity to that required to handle the room cooling load.

It was assumed above merely for purposes of example that the change in operating conditions was produced by a change in the ambient temperature of the condensing unit. However, the system also operates to produce capacity changes to meet different conditions due to changes in the evaporator ambient temperature or a combination of changes of both condensing and evaporating temperatures.

The size of the tank 15 is determined by the volume of the condenser 13 and by the proportion of the condenser surface which is to be blocked off by flooding at the extreme end of the control range. However, except for the additional heat input required to make up for higher loss in a larger tank, there is no objection to making the tank sufficiently large to contain the entire refrigerant charge of the system. The tank should be located so that it will drain completely by gravity during the shutdown period; this minimizes the accumulation of oil in the tank.

The modification of my invention illustrated in Fig. 2 is similar to that of Fig. 1 and corresponding parts have been designated by the same numerals. The system of Fig. 2 differs from that of Fig. 1 in the arrangement for controlling the interchange of liquid refrigerant between the refrigerant circuit and the tank 15. In Fig. 2 a thermosiphon pump comprising a liquid leg 30 and a liquid-vapor leg 31 is connected between the lowermost portion of the liquid line 17 and the vapor space between the upper portion of the tank 15. When it is desired to supply liquid refrigerant to the tank 15, an electric heater 32 is energized and heats liquid in the leg 31 to vaporize a portion of the liquid and change the average density of the refrigerant in that portion and also to produce a vapor lift resulting in a flow of liquid refrigerant from the liquid line 17 to the chamber 15. The return of liquid refrigerant from the chamber 15 to the line 17 is effected through a restricted duct 33 connecting the bottom of the tank with the liquid line 17. The duct 33 tends to drain the tank 15 at a substantially constant rate and the thermosiphon pump is designed to provide a maximum rate of flow of, say, twice the rate of flow through the duct 33. It is thus apparent that by control of the thermosiphon pump the average amount of liquid refrigerant in the chamber 15 may be held at any predetermined desired average level. The electric heater 32 has been shown connected to a suitable source of alternating current through a transformer 34 and the switch 22. In order to prevent any appreciable change in the operation of the thermosiphon pump because of the saturation pressure-temperature characteristics of the refrigerant, a pressure equalizing tube 35 is connected between the vapor space of the chamber 15 and the high pressure vapor space of the condensing unit, that is the high pressure space between the compressor discharge port and the liquid in the condenser.

The operation of the system shown in Fig. 2 is essentially the same as is shown in Fig. 1 except that the changes in level of the liquid refrigerant in the tank 15 are effected solely by the operation of the thermosiphon pump and no substantial transient changes are produced due to changes in the saturation pressures and temperatures.

In Fig. 3, I have illustrated another modification of my invention which is similar to that shown in Fig. 2 and corresponding parts have again been designated by the same numerals. The difference between the systems of Figs. 2 and 3 lies in the arrangement for controlling the energization of the heater 32. In Fig. 3 the heater is controlled in accordance with the amount of superheat in the vaporized refrigerant returned to the compressor instead of in accordance with the inlet evaporator temperature. The heater 32 is energized by the operation of a switch 37 which is controlled by the difference in pressure between bellows 38 and 39. The bellows 38 is provided with a thermal bulb 40 responsive to the inlet temperature of the evaporator, and the bellows 39 is provided with a thermal bulb 41 responsive to the temperature at the outlet of the evaporator. The bellows 38 tends to open the switch 37 upon an increase in temperature at the inlet of the evaporator, and the bellows 39 tends to close the switch 37 upon an increase in the temperature at the outlet of the evaporator. The difference between these temperatures is dependent upon the superheating of the refrigerant vapor withdrawn from the evaporator and the system is therefore controlled in accordance with suction vapor superheating. It is obvious that other forms of superheat sensitive controls known to the art may be employed to energize the heater 32. The arrangement of Fig. 3 is the preferred control for dry expansion systems but may be employed equally well on flooded systems; the control arrangements of Figs. 1 and 2 are primarily for systems employing normally flooded evaporators.

In the foregoing description it has been assumed by way of example that the changes in operating conditions are produced by changes in the ambient temperature of the condensing unit. It is obvious, however, that the changes may be produced by other causes such as changes in evaporator ambient temperature or in both evaporator and condensing unit ambient temperatures. Furthermore, it is recognized that refrigerating systems in which the control is dependent merely upon the evaporator pressure may be required to operate under certain unfavorable conditions which produce unsatisfactory operation because of the characteristics of the control. It is obvious, therefore, that the use of a particular type of control for a refrigerating system employing the present invention is to be selected in accordance with good practice. For example, when the evaporator of a system is subject to wide changes in ambient temperature it may become necessary to employ a control such as that of Fig. 3 which is responsive to the superheat of the withdrawn refrigerant.

It will be noted in Figs. 2 and 3 that no heat interchanger has been employed between the liquid line and the suction line. Such heat interchangers are frequently employed to better the economy of the system but are not essential to the operation of the system.

It is readily apparent from the foregoing that I have provided a simple and effective arrangement for varying the effective capacity of a refrigerating machine employing an expansion device of the fixed restrictor type and that my in-

vention provides increased range of operation for such systems.

While I have illustrated my invention in connection with refrigerating systems for cooling air, other applications will readily be apparent to those skilled in the art. I do not, therefore, desire my invention to be limited to the particular arrangement shown and described and I intend by the appended claims to cover all modifications within the spirit and scope of my invention.

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

1. A refrigerating system comprising a compressor and a condenser and an evaporator connected in series to provide a normal refrigerant circuit, a fixed restrictor in said circuit for controlling the flow of refrigerant from said condenser to said evaporator, a closed liquid refrigerant storage chamber arranged outside the normal series path of refrigerant in said circuit and having restricted communication affording passage of liquid refrigerant between said chamber and said condenser, and means dependent upon a condition of operation of said system for varying the ratio of the amount of refrigerant in said chamber to the amount in said circuit to vary the capacity of said system.

2. A refrigerating system comprising a compressor and a condenser and an evaporator connected in series to provide a normal refrigerant circuit, a fixed restrictor in said circuit for controlling the flow of refrigerant from said condenser to said evaporator, a closed liquid refrigerant storage chamber arranged outside the normal series path of refrigerant in said circuit and having restricted communication affording passage of liquid refrigerant between said chamber and said condenser, and means dependent upon the temperature of the refrigerant admitted to said evaporator for controlling the interchange of liquid refrigerant between said chamber and said circuit to vary the capacity of said system.

3. A refrigerating system comprising a compressor and a condenser and an evaporator connected in series to provide a normal refrigerant circuit, a fixed restrictor in said circuit for controlling the flow of refrigerant from said condenser to said evaporator, a closed liquid refrigerant storage chamber arranged outside the normal series path of refrigerant in said circuit and having restricted communication affording passage of liquid refrigerant between said chamber and said condenser, and means dependent upon a condition of operation of said system for supplying heat to said chamber to determine the amount of refrigerant stored in said chamber whereby the capacity of said system is varied in accordance with said condition of operation.

4. A refrigerating system comprising a compressor and a condenser and an evaporator connected in series to provide a normal refrigerant circuit, a fixed restrictor in said circuit for controlling the flow of refrigerant from said condenser to said evaporator, a closed liquid refrigerant storage chamber arranged outside the normal series path of refrigerant in said circuit and having restricted communication affording passage of liquid refrigerant between said chamber and said condenser, and means dependent upon the difference in temperature between the inlet of said evaporator and the outlet thereof and controlling the relative amounts of refrigerant in said chamber and in said circuit for varying the capacity of said system.

5. A refrigerating system comprising a compressor and a condenser and an evaporator connected in series to provide a normal refrigerant circuit, a fixed restrictor in said circuit for controlling the flow of refrigerant from said condenser to said evaporator, a closed liquid refrigerant storage chamber arranged outside the normal series path of refrigerant in said circuit and having restricted communication affording passage of liquid refrigerant between said chamber and said circuit, means including a thermosyphon pump for conveying liquid refrigerant from said circuit to said chamber, and means dependent upon a condition of operation of said system for operating said pump to determine the amount of refrigerant stored in said chamber whereby the capacity of said system is varied in accordance with said condition of operation.

6. A refrigerating system comprising a condensing unit and an evaporating unit and a fixed restrictor for controlling the flow of refrigerant from said condensing unit to said evaporating unit, means including a closed thermally insulated chamber for storing a quantity of liquid refrigerant and for restricting the circulation of said quantity of liquid refrigerant through said system, and means dependent upon a condition of operation of said system for effecting an interchange of liquid between said system and said chamber for varying the ratio of the amount of refrigerant in said chamber to the amount in the remainder of said system whereby the capacity of said system is varied in accordance with said condition.

7. A refrigerating system comprising a condensing unit and an evaporating unit and a fixed restrictor for controlling the flow of refrigerant from said condensing unit to said evaporating unit, means including a closed thermally insulated chamber for storing a quantity of liquid refrigerant and for preventing the circulation of said quantity of liquid refrigerant through said system, means including a thermosyphon pump and a restricted return duct for effecting an interchange of liquid refrigerant between said system and said chamber, and means dependent upon a condition of operation of said system for actuating said pump to determine the relative amounts of refrigerant in said chamber and in the remainder of said system.

8. A refrigerating system comprising a condensing unit and an evaporating unit and a fixed restrictor for controlling the flow of refrigerant from said condensing unit to said evaporating unit, means including a closed chamber arranged in an ambient having a temperature lower than the condensing temperature of refrigerant in said system for storing a quantity of liquid refrigerant and for restricting the circulation of said quantity of liquid refrigerant through said system, and means dependent upon a condition of operation of said system for effecting an interchange of liquid between said system and said chamber for varying the ratio of the amount of refrigerant in said chamber to the amount in the remainder of said system whereby the capacity of said system is varied in accordance with said condition.

9. A refrigerating system comprising a compressor and a condenser and an evaporator connected in series to provide a normal refrigerant circuit, said circuit including a fixed restrictor for controlling the flow of refrigerant from said condenser to said evaporator, a closed liquid refrigerant storage chamber arranged outside the normal series path of refrigerant in said circuit and

having a duct affording restricted communication between the lower portion of said chamber and said circuit whereby liquid refrigerant may flow by gravity from said chamber, means including a thermosyphon pump having an outlet in the upper portion of said chamber for conveying liquid refrigerant from said circuit to said chamber, means dependent upon a condition of operation of said system for operating said pump to determine the amount of refrigerant stored in said chamber whereby the capacity of said system is varied in accordance with said condition of operation, and a restricted duct connecting the upper portion of said chamber and said circuit on the discharge side of said condenser for equalizing the pressure within said chamber and within said condenser.

10. A refrigerating system comprising a condensing unit and an evaporating unit and a fixed restrictor for controlling the flow of liquid refrigerant from said condensing unit to said evaporating unit, means providing a closed chamber having restricted communication with said condensing unit for storing a quantity of liquid refrigerant and for restricting the circulation of said quantity of liquid refrigerant through said system, means dependent upon a condition of operation of said system for heating said chamber to effect an interchange of liquid between said condensing unit and said chamber for varying the capacity of said system in accordance with said condition, and a restricted duct connecting said chamber above the level of liquid therein with a relatively low pressure portion of said condensing unit for removing noncondensable gas from said chamber.

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