

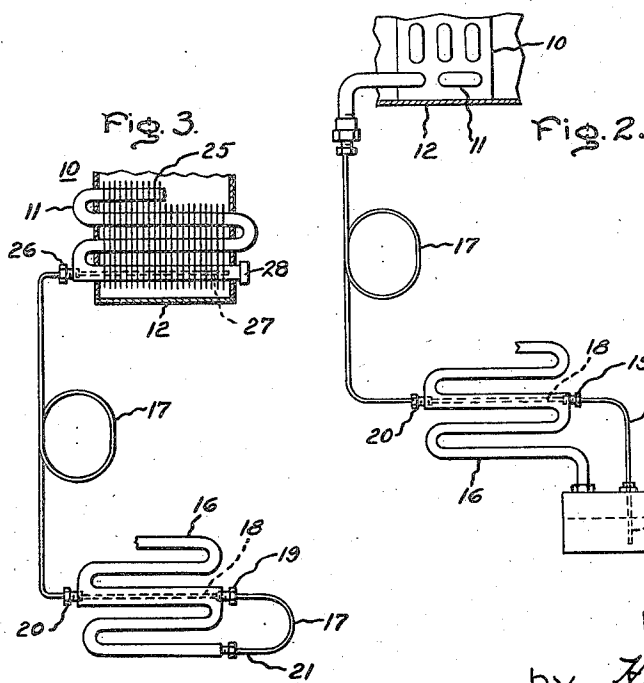
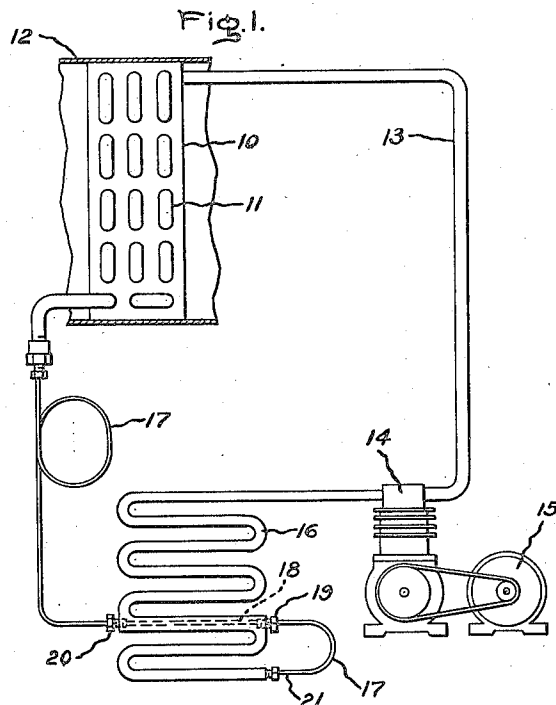
July 16, 1946.

F. O. URBAN  
REFRIGERATING MACHINE

2,404,112

Filed Jan. 19, 1943

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

Fig. 4.

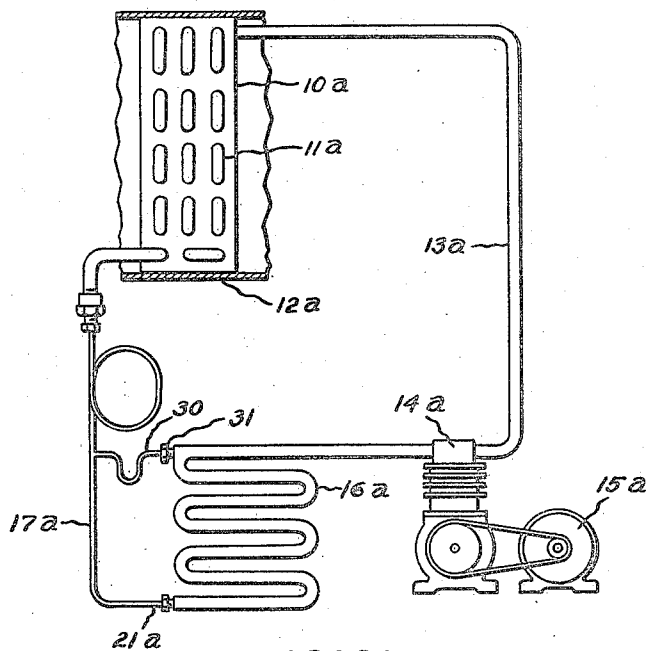
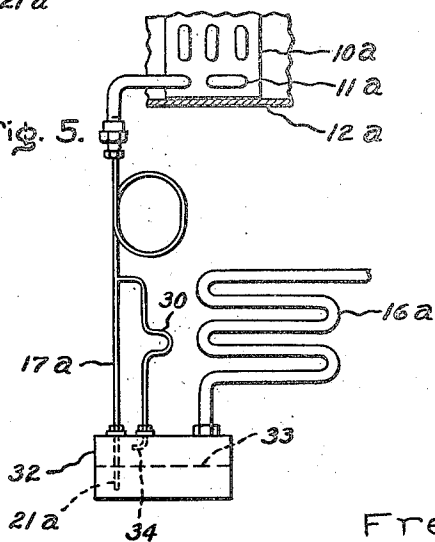


Fig. 5.



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## UNITED STATES PATENT OFFICE

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## REFRIGERATING MACHINE

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13 Claims. (Cl. 62—8)

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My invention relates to refrigerating machines and particularly to such machines having elongated restrictors or capillary tubes for controlling the flow of liquid refrigerant from the condensing apparatus to the evaporator.

Refrigerating machines generally comprise an apparatus for condensing gaseous refrigerant to provide liquid refrigerant at a relatively high pressure which is then supplied through some suitable pressure reducing device to an evaporator where the liquid is vaporized by the absorption of heat from the medium surrounding the evaporator, the vaporized refrigerant being withdrawn from the evaporator and returned to the condensing apparatus. Various types of mechanically operated valves have been employed to regulate the flow of liquid refrigerant from the condensing apparatus to the evaporator. However, satisfactory operation over at least a limited range of operating temperatures of the condensing apparatus can be obtained by employing a length of tubing having a small internal diameter such that it presents resistance to the flow of refrigerant and effects a gradual reduction of pressure from the high pressure at the condensing apparatus to the low pressure at the evaporator. These tubes are commonly called restrictors or capillary tubes. The rate of flow of refrigerant through the capillary tube depends upon the difference in pressure between the intake and discharge ends of the tube, and, in any particular case, is determined by the length of the tube and the cross-sectional area of its passage. It is common practice to design the capillary tube for a given machine so that it will conduct the requisite flow of refrigerant to the evaporator under a predetermined pressure difference. Normally some of the liquid refrigerant vaporizes within the capillary tube during its passage therethrough and this vaporization of liquid determines to a considerable extent the rate of flow of refrigerant through the tube. As the pressure difference increases a condition is reached such that the capillary tube can convey the liquid refrigerant to the evaporator at a greater rate than it is condensed, and consequently efficiency of operation is lost. For many types of operation it is desired to provide a refrigerant control device which will pass the same amount of liquid refrigerant over a wide range of pressure differences between the high and low pressure sides and over a wide range of operating temperatures or pressures of the condensing apparatus. For example, when the evaporator load and temperature vary over a relatively

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small range while the temperature and pressure of the condensing apparatus vary over a wide range it is desirable to prevent the admission of excess refrigerant to the evaporator during the high pressure conditions in the condensing apparatus. Accordingly, it is an object of my invention to provide a refrigerating machine of the type employing a capillary tube for controlling the flow of liquid refrigerant to the evaporator and including an improved arrangement for maintaining the flow of liquid refrigerant within predetermined limits over a wide range of operating conditions.

Another object of my invention is to provide a refrigerating machine employing a capillary tube restrictor between the condensing apparatus and the evaporator, and an improved arrangement for compensating for changes in the pressure within the condensing apparatus.

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 drawings in which Fig. 1 illustrates diagrammatically a refrigerating machine embodying my invention; Figs. 2 and 3 illustrate modifications of the arrangement shown in Fig. 1; and Figs. 4 and 5 illustrate diagrammatically two modifications of a further embodiment of my invention.

Briefly, the refrigerating machine shown in the drawings comprises an evaporator and a condensing apparatus for liquefying vaporized refrigerant withdrawn from the evaporator and a capillary tube restrictor for controlling the return of liquid refrigerant from the condensing apparatus to the evaporator. In order to maintain the flow of refrigerant through the capillary tube substantially constant regardless of changes in temperature and pressure within the condensing apparatus there is provided an arrangement for increasing the proportion of vaporized refrigerant passing through the capillary tube in accordance with increases in pressure within the condensing apparatus. In one arrangement illustrated a portion of the capillary tube spaced from the inlet is supplied with heat from the condenser so that heat is supplied to that portion of the capillary tube in accordance with the changes in pressure in the condenser. In another of the illustrated arrangements a second capillary tube is connected to conduct high pressure

gaseous refrigerant from the condenser to an intermediate portion of the flow controlling capillary tube; this arrangement introduces additional vaporized refrigerant to vary the flow with condenser pressure so that an increase in pressure in the condenser will not produce a corresponding increase in the amount of refrigerant flowing to the evaporator.

Referring now to the drawings the refrigerating machine shown in Fig. 1 comprises an evaporator 10 comprising a zig-zag tubing 11 and arranged within an air duct 12 to cool the air passing through the duct. Heat is absorbed from the air passing through the duct and liquid refrigerant within the evaporator is vaporized and the vapor is withdrawn through a suction line 13 by operation of a compressor 14 driven by an electric motor 15. The vaporized refrigerant after having been compressed is discharged to a condenser 16 which may be cooled in any suitable manner in accordance with usual refrigeration practice. The cooled compressed refrigerant is liquefied within the condenser 16 and flows from the condenser through a capillary tube or elongated restrictor 17 back to the evaporator 10.

During the operation of the refrigerating machine the temperature of the medium, such as air, employed to cool the condenser 16 may vary over a wide range so that the pressure of the refrigerant within the condenser will vary accordingly. As the pressure in the condenser is increased the difference of pressure between the inlet and outlet ends of the tube 17 is increased and more refrigerant tends to flow through the capillary tube. However, the evaporator 10 does not require additional refrigerant and consequently it is desirable to limit the flow of refrigerant through the capillary tube 17 so that it does not increase substantially with the increased pressure in the condenser. In order to counteract the tendency toward increased flow of refrigerant through the capillary tube, I arrange a portion of the tube spaced from its inlet and in heat exchange relation with the condenser so that the temperature of this portion of the tube varies in accordance with changes in temperature and pressure within the condenser. Referring again to Fig. 1 a portion of the tube indicated at 18 passes directly through the condenser, suitable connectors 19 and 20 being provided to seal the condenser where the tube 17 enters and leaves it, respectively. During the operation of the refrigerating machine the liquid refrigerant which enters the tube 17 decreases in pressure as it flows toward the connection 19 so that when it enters the portion 18 within the condenser its pressure is lower than the saturation pressure corresponding to the temperature of the liquid refrigerant which enters the inlet 21. As the refrigerant within the tube 17 passes through the portion 18 it receives heat from the refrigerant within the condenser and some of the liquid refrigerant within the tube 17 is vaporized, thereby increasing the proportion of gaseous refrigerant flowing through the tube and decreasing the flow of liquid refrigerant through the tube. The tendency to decrease the flow of liquid refrigerant will vary with the pressure within the condenser, since the temperature of the portion 18 depends upon and varies with the pressure within the condenser. When the pressure within the condenser 16 is at the upper end of its range of operating pressures the temperature of the portion 18 will be increased accordingly and there will be greater vaporization of refrigerant within

the tube 17 and consequently the flow of refrigerant through the capillary tube will be decreased substantially over that which would occur were the heat exchange portion 18 not provided. As the pressure and temperature of the condenser become lower the effect of vaporization within the portion 18 of the tube 17 is decreased. Consequently, the resistance to flow of refrigerant through the tube 17 is decreased so that, although the pressure difference between the inlet and outlet of the tube 17 has decreased substantially, the decrease in the resistance of the tube to flow compensates for the loss in pressure difference, and the evaporator 10 is supplied with its required amount of liquid refrigerant. In other words, the flow of refrigerant to the evaporator is maintained within predetermined acceptable limits regardless of changes of pressure in the condenser.

The arrangement shown in Fig. 2 is similar to that shown in Fig. 1 and corresponding parts have been designated by the same numerals. The only difference between the systems of Fig. 1 and Fig. 2 lies in the provision of a liquid receiver 22 for collecting liquid refrigerant formed in the condenser 16. The inlet end 21 of the tube 17 opens directly into the lower portion of the receiver 22 below the level of liquid refrigerant therein. The receiver 22 is employed to prevent the admission of gaseous refrigerant to the tube 17 during the normal operating range of the refrigerating system and to provide a storage space for condensed liquid which is outside the condenser proper. The operation of the system shown in Fig. 2 is the same as that shown in Fig. 1 and as described above.

The refrigerating machine illustrated in Fig. 3 is similar to that illustrated in Figs. 1 and 2 and corresponding parts have been designated by the same numerals. The duct and evaporator in Fig. 3 have been shown at right angles to their position in Fig. 1 in order to show the modification more clearly, and heat exchange fins 25 appear in this view. The capillary tube 17 enters the lowermost turn of the tubing 11 through a connection 26, and a portion 27 of the tube extends through the tubing 11 toward a closed end 28 so that refrigerant entering the evaporator from the capillary tube enters the end 28 and flows back in counterflow to the refrigerant within the tube. Furthermore, the lowermost portion of the evaporator is normally filled with liquid refrigerant so that the portion 27 of the capillary tube is below the level of liquid refrigerant and subject to the temperature of the boiling liquid during operation of the evaporator. The arrangement of the portion 18 in heat exchange with the condenser operates in the same manner as in the modifications of Figs. 1 and 2. The portion 27 within the evaporator 10 operates to assist the heat exchange portion 18 and to provide similar compensation depending upon the pressure changes in the evaporator which are accompanied by corresponding changes in the temperature of the boiling liquid. The arrangement of the portion 27 within the boiling liquid makes the refrigerant within the capillary tube more sensitive to changes in pressure with the evaporator than would be possible if this portion were merely arranged in heat exchange with the vaporized gas. During the operation of the refrigerating system should the condensing pressure decrease there will result a reduction in flow through the capillary tube which in turn causes a reduction in the pressure within the evaporator. The reduc-

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tion of pressure within the evaporator lowers the temperature of the boiling liquid and the amount of vaporized refrigerant within the portion 27 of the tube is reduced by condensation; this lowers the resistance of the tube and more refrigerant flows to the evaporator to compensate for the pressure reduction and restores normal evaporator temperature. Obviously an increase in condensing pressure has the opposite effect. By providing the capillary tube 17 with the two portions 18 and 27 in heat exchange with the condenser and evaporator, respectively, there is provided a sensitive and reliable arrangement for regulating the flow of liquid refrigerant through the capillary tube to maintain the flow within predetermined acceptable limits regardless of changes in pressure within the condensing apparatus.

The refrigerating machine shown in Fig. 4 is similar to that shown in Fig. 1 and corresponding parts have been designated by the same numerals followed by the letter "a." However, a different arrangement is provided for varying the amount of vaporized refrigerant flowing through the capillary tube in accordance with changes in pressure within the condenser. The capillary tube 17a has an intermediate point connected by a length of capillary tube 30 to the condenser 16a through a connection 31 at the top thereof. The capillary tube 30 introduces vaporized refrigerant from the high pressure side of the condensing unit, and the amount of vaporized refrigerant introduced obviously depends upon the pressure difference across the tube 30 which varies with the pressure within the condenser 16a. When the pressure within the condenser 16a is decreased, for example because of a decrease in the temperature of the cooling medium, the amount of vaporized refrigerant introduced by the tube 30 in the path of the refrigerant flowing through the tube 17a is decreased and the resistance to flow within the tube 17a is decreased so that although there is a decrease in the pressure difference across the tube 17a the resistance of the tube is also decreased and the amount of refrigerant flowing to the evaporator is not materially changed.

The system shown in Fig. 5 is similar to that shown in Fig. 4 and corresponding parts are designated by the same numerals. This system includes a liquid receiver 32 in which liquid is collected to a level 33. The capillary tube 17a enters the receiver 32 and the inlet 21a of the tube 17a is located below the level of liquid refrigerant 33 so that only liquid refrigerant enters the inlet 21a. The capillary tube 30 for introducing gaseous refrigerant at an intermediate point between the ends of tube 17a is connected in communication with the upper portion of the receiver 32 as indicated at 34 so that gaseous refrigerant separated from the liquid within the receiver at the condenser pressure enters the tube 30 from the receiver.

In the refrigerating machines of Figs. 4 and 5 the length of the capillary tube 17a, the point at which the tube 30 admits uncondensed vapor to the tube 17a and the length and diameter of the tube 30 are selected so that the desired degree of compensation is obtained. The direct admission of uncondensed vapor to the tube 17a as compared with the heat exchange arrangements of Figs. 1 and 2, has the advantage that there is relatively little time delay between a change of pressure within the condenser and the compensating action produced by the change. Obviously

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the arrangements of Figs. 4 and 5 may be employed as well as those of Figs. 1 and 2 with the capillary tube outlet compensating arrangement shown in Fig. 3.

The constructions of Figs. 4 and 5 form the subject matter of my copending application Serial No. 510,105, filed November 13, 1943, which is a division of the present application and is assigned to the same assignee.

Although the refrigerant flow controlling arrangements described herein are intended primarily for application to refrigerating machines in which the evaporator conditions remain substantially constant, appreciable regulation may also be obtained under proper conditions in systems where there is a variation in evaporator pressure and where the condenser pressure remains substantially constant; and regulation may be expected in some systems to compensate for changes in pressure drop across the capillary tube regardless of whether it is due to evaporator pressure changes or to condenser pressure changes. It has been found that in a system employing a capillary tube flow controlling device there is a critical pressure of the evaporator below which the change in pressure in the evaporator has substantially no effect upon the rate of flow through the capillary tube; effective compensation for changes in evaporator pressure may be obtained provided the system is operating with the evaporator pressure above this critical pressure.

All of the compensating arrangements described above may be employed with any of the well known types of refrigerating systems. For example, the use of this compensating device does not preclude the use of efficiency increasing devices such as the commonly employed heat exchanger between the liquid and suction lines of a refrigerating machine.

From the foregoing it is readily apparent that I have provided a simple and effective arrangement for increasing the useful range of operation of a capillary tube employed as a pressure reducing device in a refrigerating machine in which there may be a wide range of pressures within the condensing apparatus.

While I have shown particular arrangements of my invention in connection with a compressor type mechanical refrigerating system other applications and embodiments will readily be apparent to those skilled in the art. I do not, therefore, desire my invention to be limited to the particular constructions and combinations of compensating arrangements shown and described and I intend in 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 machine including an evaporator, means for withdrawing vaporized refrigerant from said evaporator, means for liquefying the withdrawn refrigerant, a restrictor tube for supplying liquid refrigerant from said liquefying means to said evaporator, said tube during at least a portion of the range of operation of said machine producing a reduction of refrigerant pressure sufficient to cause vaporization of liquid refrigerant within said tube, and means directly responsive to a condition of operation of said liquefying means and attached to a portion of said tube spaced from both ends of said tube for varying the proportion of vaporized refrigerant with respect to liquid refrigerant in said portion

of said tube in accordance with changes in the pressure difference between the ends of said tube.

2. A refrigerating machine including an evaporator, means for withdrawing vaporized refrigerant from said evaporator, means for liquefying the withdrawn refrigerant, a restrictor tube for supplying liquid refrigerant from said liquefying means to said evaporator, and means directly responsive to a condition of operation of said liquefying means and attached to a portion of said tube spaced from both ends of said tube for heating said portion in accordance with changes in the pressure difference between the ends of said tube to maintain the rate of flow of refrigerant through said tube within predetermined limits regardless of changes in said pressure difference.

3. A refrigerating machine including an evaporator, means for withdrawing vaporized refrigerant from said evaporator, means for liquefying the withdrawn refrigerant, a restrictor tube for supplying liquid refrigerant from said liquefying means to said evaporator, said tube during at least a portion of the range of operation of said machine producing a reduction of refrigerant pressure sufficient to cause vaporization of liquid refrigerant within said tube, and means directly responsive to the pressure of refrigerant within said liquefying means and attached to a portion of said tube spaced from both ends of said tube for varying the proportion of vaporized refrigerant with respect to liquid refrigerant in said portion of said tube in accordance with changes in the pressure of the refrigerant in said liquefying means.

4. A refrigerating machine including an evaporator, means for withdrawing vaporized refrigerant from said evaporator, means for liquefying the withdrawn refrigerant, a restrictor tube for supplying liquid refrigerant from said liquefying means to said evaporator, and means directly responsive to a condition of operation of said liquefying means and attached to a portion of said tube intermediate the ends thereof to heat said portion for maintaining the flow of refrigerant through said tube within predetermined limits regardless of changes of pressure within said liquefying means.

5. A refrigerating machine including an evaporator, means for withdrawing vaporized refrigerant from said evaporator, means for condensing the withdrawn refrigerant to liquefy the same, a capillary tube restrictor for conducting liquid refrigerant from said condensing means to said evaporator, and means providing heat exchange between said condenser and a portion of said tube intermediate the ends thereof to heat said portion in accordance with the temperature of said condensing means for maintaining the flow of refrigerant to said evaporator within predetermined limits regardless of changes of pressure within said condensing means.

6. A refrigerating machine including an evaporator and a compressor and a condenser, a capillary tube for conducting liquid refrigerant from said condenser to said evaporator, and means providing heat exchange between a portion of said capillary tube and said condenser to heat said portion in accordance with the temperature of said condenser for maintaining the flow of refrigerant through said tube within predetermined limits regardless of changes of pressure of refrigerant in said condenser.

7. A refrigerating machine including an evaporator, a compressor for withdrawing vaporized refrigerant from said evaporator, a condenser for

liquefying refrigerant discharged from said compressor, a capillary tube for conducting liquid refrigerant from said condenser to said evaporator, said capillary tube during at least some condition of operation of said machine reducing the pressure of liquid refrigerant within said tube sufficiently to vaporize a portion thereof within said tube, and means directly responsive to a condition of operation of said condenser and attached to a portion of said tube at substantial distances from both ends of said tube for increasing the proportion of vaporized refrigerant in said portion in accordance with an increase of pressure in said condenser.

8. A refrigerating machine including an evaporator and a compressor and a condenser, a capillary tube for controlling the flow of liquid refrigerant from said condenser to said evaporator, and means providing heat exchange between a portion of said capillary tube and said condenser to heat said portion in accordance with the temperature of said condenser for maintaining the flow of refrigerant through said tube within predetermined limits regardless of changes of the pressure of refrigerant in said condenser, said portion of said capillary tube being located intermediate the ends of said tube and being spaced from the inlet end thereof whereby the refrigerant entering said portion of said capillary tube is at a pressure below the pressure corresponding to the temperature of the liquid refrigerant entering said capillary tube.

9. A refrigerating machine including an evaporator and a compressor and a condenser, a capillary tube for controlling the flow of liquid refrigerant from said condenser to said evaporator, said capillary tube being connected to pass through said condenser whereby a portion of said capillary tube lies within said condenser in heat exchange with the refrigerant in said condenser and the flow of refrigerant through said tube is modified inversely in accordance with the pressure in said condenser, said portion of said capillary tube being spaced from the inlet end of said tube whereby the pressure of the refrigerant entering said portion of said capillary tube is lower than the pressure corresponding to the temperature of the liquid refrigerant entering said tube.

10. A refrigerating machine including an evaporator and a compressor and a condenser, a receiver for collecting refrigerant liquefied within said condenser, a capillary tube having its inlet end located below the level of liquid refrigerant in the receiver for controlling the flow of liquid refrigerant from said receiver to said evaporator, and means providing heat exchange between a portion of said capillary tube and said condenser for maintaining the flow of refrigerant through said tube within predetermined limits regardless of changes of the pressure of refrigerant in said condenser.

11. A refrigerating machine including an evaporator, means for withdrawing vaporized refrigerant from said evaporator, means for liquefying the withdrawn refrigerant, a restrictor tube for supplying liquid refrigerant from said liquefying means to said evaporator, said tube during at least a portion of the range of operation of said machine producing a reduction of refrigerant pressure sufficient to cause vaporization of liquid refrigerant within said tube, means associated with said tube intermediate the ends thereof for controlling the proportion of vaporized refrigerant with respect to the liquid refrigerant flowing

through said tube in accordance with the pressure of the refrigerant in said liquefying means, and means providing heat exchange between a portion of said tube adjacent its outlet end and the liquid refrigerant within said evaporator for assisting said pressure dependent means to control the proportion of vaporized refrigerant flowing through said tube to said evaporator.

12. A refrigerating machine including an evaporator, means for withdrawing vaporized refrigerant from said evaporator, means for liquefying the withdrawn refrigerant, a restrictor tube for supplying liquid refrigerant from said liquefying means to said evaporator, means for variably heating a portion of said tube intermediate the ends thereof in accordance with variations of the pressure in said liquefying means for maintaining the flow of refrigerant through said tube within predetermined limits regardless of pressure changes within said liquefying means, and a portion of said tube adjacent the outlet end thereof

being arranged in heat exchange with liquid refrigerant within said evaporator for assisting said pressure dependent means in maintaining the flow of refrigerant through said tube within said predetermined limits.

13. A refrigerating machine including an evaporator, means for withdrawing vaporized refrigerant from said evaporator, means for condensing the withdrawn refrigerant to liquefy the same, a capillary tube restrictor for conducting liquid refrigerant from said condensing means to said evaporator, and means providing heat exchange between said condenser and a portion of said tube intermediate the ends thereof and providing heat exchange between liquid refrigerant in said evaporator and a portion of said tube adjacent the outlet end thereof for maintaining the flow of refrigerant to said evaporator within predetermined limits regardless of changes of pressure within said condensing means.

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