United States Patent

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[73] Assignee Emerson Electric Co.

[54] CONTROL FOR REFRIGERATION SYSTEM
3 Claims, 6 Drawing Figs.

[52] U.S. Cl. 62/196, 62/221, 62/503, 62/DIG. 2
[51] Int. Cl. F25b 41/00
[50] Field of Search .... 62/196, 498 P, 503, 220, 221, 471

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ABSTRACT: A control in a refrigeration system to control the rate of flow of refrigerant to the evaporator in response to variations in rate of flow of liquid refrigerant from the evaporator. A sump in the suction line between the evaporator and compressor for collecting liquid discharged with vapor from the evaporator. A pump for pumping liquid at a controlled rate from the sump for mixture with the vapor supplied from the upper end of the sump to the compressor. A liquid level sensor for sensing changes in the level of liquid within the sump and for controlling operation of an expansion valve on the inlet side of the evaporator in response to variations of liquid within the sump.

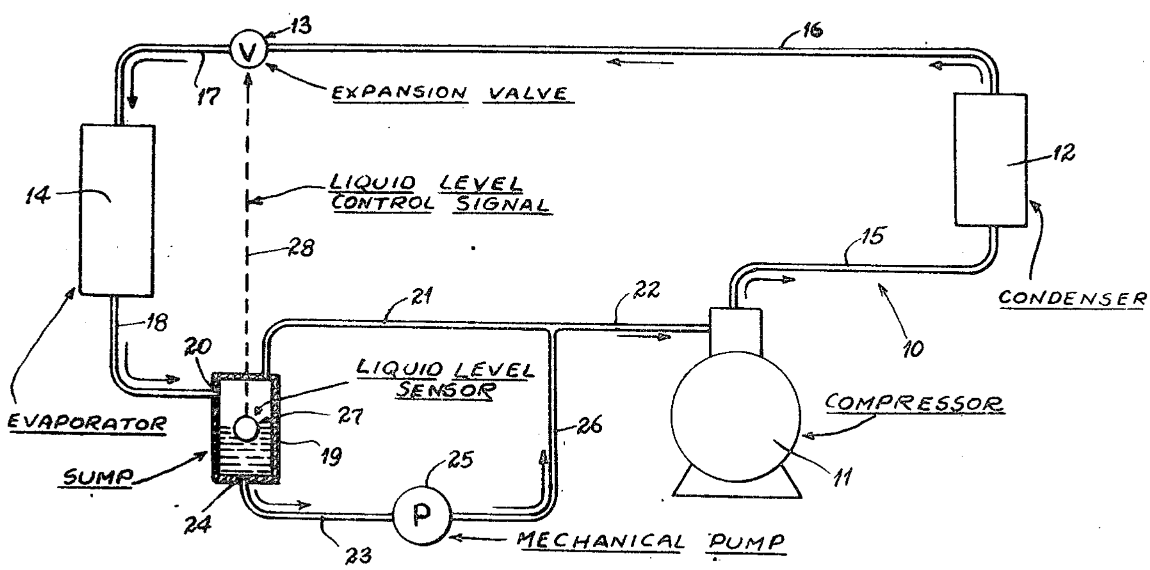

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Fig.1.

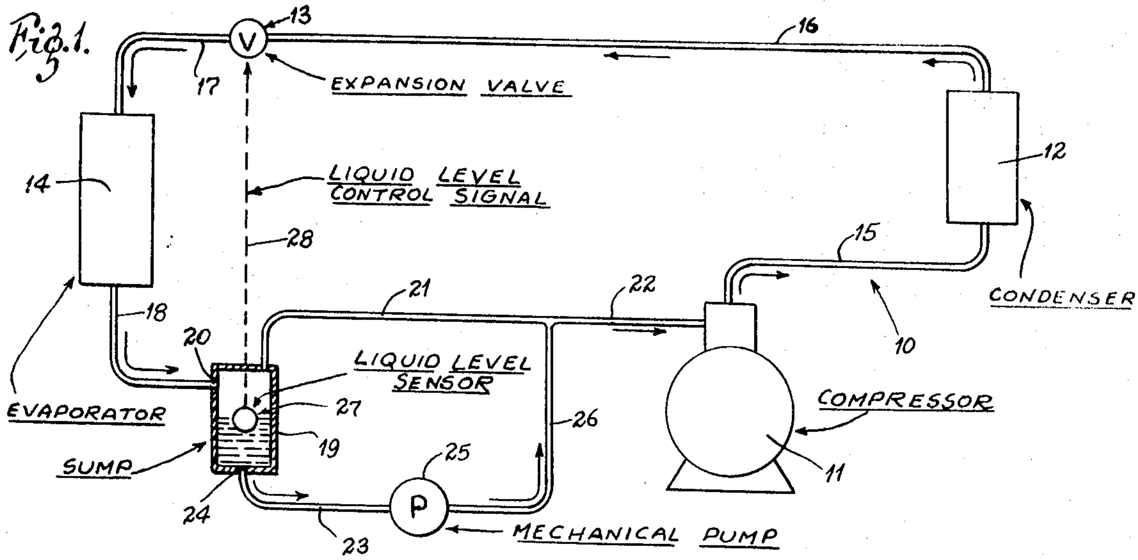


Fig.2.

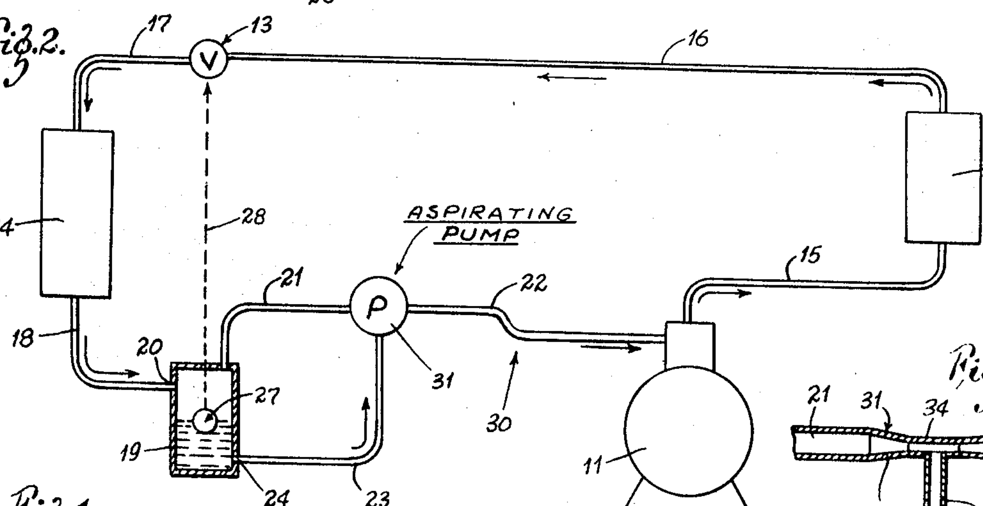


Fig.3.

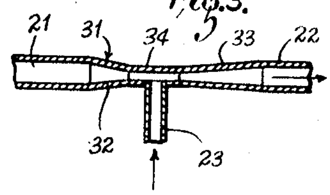


Fig.4.

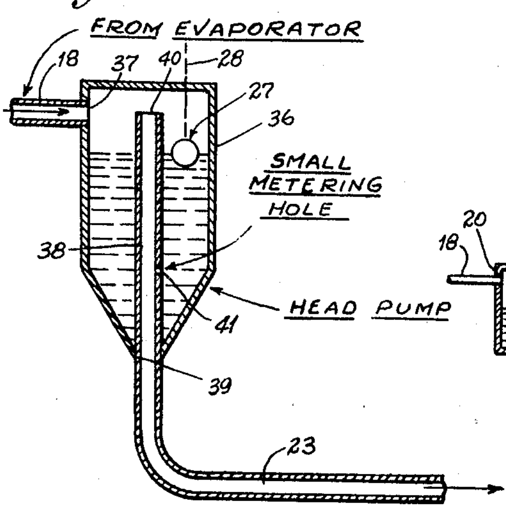


Fig.5.

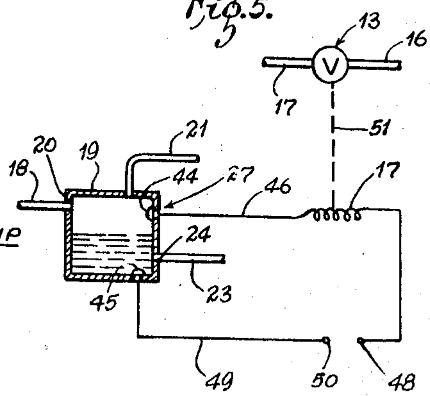
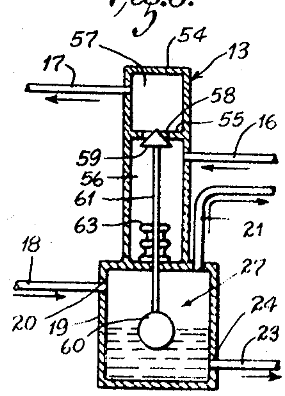


Fig.6.



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CONTROL FOR REFRIGERATION SYSTEM

BRIEF DESCRIPTION OF THE INVENTION

This control regulates operation of an expansion valve in a refrigeration system. The expansion valve is connected between the condenser and the evaporator of the refrigeration system with the compressor having its suction side supplied from the evaporator and having its discharge side connected to the condenser. The control includes a sump connected on the outlet side of the evaporator. Refrigerant flowing from the evaporator is discharged into the upper end of the sump to permit liquid refrigerant to fall to the lower end of the sump while refrigerant vapor remains in the upper end of the sump. A tube leads from the suction side of the compressor so that when the compressor operates, it draws refrigerant vapor from the upper end of the sump. A pump delivers liquid refrigerant from the lower end of the sump at a controlled rate into mixture with the vapor being supplied to the compressor.

The level of liquid within the sump tends to vary with the rates of evaporation of refrigerant in the evaporator and, of course, with the rate of supply of refrigerant to the evaporator as set by the expansion valve. There is a liquid level sensor within the sump to sense these variations in liquid level with a means for controlling operation of the expansion valve in response to variations in the level of liquid within the sump. In this manner, the control regulates operation of the expansion valve to cause the rate of supply of liquid refrigerant to the evaporator to be varied in direct response to variations in the rate of flow of liquid from the evaporator.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram of a refrigeration system having the control of this invention and utilizing a mechanical pump;

FIG. 2 is a schematic diagram showing the use of an aspirating pump in the control system;

FIG. 3 is an enlarged sectional view of a venturi-type aspirating pump used in the control illustrated in FIG. 2;

FIG. 4 is a schematic section view of a combination sump and head pump replacing the sump and pump of FIG. 1 or FIG. 2;

FIG. 5 is a schematic diagram of one form of control of the expansion valve according to liquid level within the sump; and

FIG. 6 is a schematic sectional view of another form of control of the expansion valve according to the liquid level in the sump.

DETAILED DESCRIPTION OF THE INVENTION

As shown in FIG. 1, the system **10** has a compressor **11**, a condenser **12**, an expansion valve **13**, and an evaporator **14**. The discharge side of the compressor **11** is connected by a tube **15** to the inlet to the condenser **12**. The condenser outlet is connected by a tube **16** to the inlet to the expansion valve **13**. The outlet from the expansion valve **13** is connected by a tube **17** to the inlet to the evaporator **14**. A tube **18** leads from the outlet of the evaporator **14** to a sump **19**. The tube **18** is connected through an opening **20** in a sidewall of the sump **19** adjacent the upper end of the sump **19**. Another tube **21** extends through an opening in a wall adjacent the upper end of the sump **19** and leads to a tube **22** connected to the suction side of the compressor **11**. A tube **23** extends through an opening **24** in a wall adjacent the bottom of the sump **19** and leads to a pump **25**, such as a conventional mechanical pump. The discharge side of the pump **25** is connected by a tube **26** to the juncture between the tubes **21** and **22**.

The sump **19** is vapor tight and has a suitable liquid level sensor **27** within it. A control means **28** of any desired kind is connected from the liquid level sensor **27** to the valve **13** for controlling operation of the valve **13** in response to variations of the liquid level within the sump **19**.

OPERATION OF THE CONTROL SYSTEM OF FIG. 1

The refrigeration system operates in the usual manner with the compressor **11** receiving low pressure vapor from the tube **22** and discharging high pressure vapor through the tube **15** to the condenser **12** where the vapor is condensed to liquid. The liquid is supplied from the condenser **12** through the tube **16** to the expansion valve **13**. The expansion valve **13** regulates the rate of supply of the liquid to the evaporator **14** and also lowers the pressure of the liquid that is supplied to the evaporator. As the liquid refrigerant circulates through the evaporator **14**, it absorbs heat from the medium surrounding the evaporator **14**, changing the state of most of the refrigerant from liquid to vapor or gas. The vapor or gas with a small amount of liquid travels through the tube **18** and the opening **20** to the sump **19**. Since the opening **20** is adjacent the upper end of the sump **19**, liquid refrigerant entering from the tube **18** can fall toward the lower end of the sump **19** while the vapor occupies the space above the liquid level within the sump **19**. Since the tube **21** is connected through an opening adjacent the upper end of the sump **19** and above the liquid level therein, no liquid will flow through the tube **21**, and vapor from the sump **19** can flow through the tube **21** and the tube **22** to the suction side of the compressor **11**.

The liquid level sensor **27** and its means for delivering a controlled signal through the connection **28** may be of any suitable design. Likewise, the pump **25** may be of any suitable design.

Liquid is collected in the sump **19** as liquid is discharged with the vapor from the evaporator **14**. The purpose of the sump **19** is to control operation of the expansion valve **13** to regulate the flow of liquid to the evaporator **14** in response to the rate of flow of liquid from the evaporator **14** to the sump **19**. Under ideal operating conditions, the refrigerant discharged from the evaporator primarily constitutes vapor with only a very small percentage of liquid. This liquid is admitted with the vapor through the opening **20** to the sump **19**, and the liquid falls by gravity to the lower portion of the sump **19**. If desired, the inlet **20** may be tangential to the sidewall of the sump **19** to facilitate downward separation of the liquid as the refrigerant swirls in a vortex at the upper end of the sump.

The pump **25** is a very low capacity pump, having only a small fraction of the flow capacity of the compressor **11**. The pump **25** draws liquid at a low but controlled rate from the sump **19** and discharges the liquid through the tube **26** into the tube **22** that supplies refrigerant to the compressor **11**. This small amount of liquid will normally be vaporized by heat generated by operation of the compressor **11** and the compressor motor. The small and controlled rate of flow of liquid refrigerant to the compressor **11** helps cool the compressor motor.

If the load on the evaporator **14** is reduced, or if the rate of supply of refrigerant to the evaporator **14** is too high for any other reason, less than the optimum rate of evaporation of the refrigerant will take place. Consequently, the refrigerant flowing through the tube **18** from the evaporator **14** will contain more than the normal amount of liquid. When this greater amount of liquid enters the sump **19**, it raises the level of liquid within the sump **19** since the pump **25** is always withdrawing liquid at a constant rate. When the liquid level within the sump **19** rises, the rising level is sensed by the liquid level sensor **27**. The sensor **27** transmits a signal through the control means **28** to the expansion valve **13** to either throttle or close the expansion valve **13**. This reduces or stops the flow of refrigerant through the evaporator so that less liquid refrigerant is available in the evaporator for absorption of heat from the surrounding medium. Consequently, a greater proportion of the refrigerant will be evaporated in the evaporator, decreasing the rate of supply of liquid from the evaporator **14** to the sump **19**. As the rate of liquid supplied to the sump **19** decreases, due to reduced or wholly interrupted supply of refrigerant to the evaporator **14**, the liquid level within the sump 19 drops, inasmuch as the pump 25 continues to pump liquid from the sump 19 at its normal rate. As the liquid level within the sump 19 drops, the lowered liquid level is sensed by the liquid level sensor 27 and it transmits a signal through the control means 28 to the valve 13 to open the valve.

Thus the control of this invention improves the efficiency of the evaporator 14 by reducing the required heat exchange surface in the evaporator which would otherwise be required for superheating the refrigerant before the refrigerant emerges from the evaporator. In addition, a small but controlled rate of flow of liquid is supplied to the compressor 11. This small and controlled amount of liquid provides some cooling for the compressor motor.

FIG. 2 illustrates a modification of the control system wherein all the components are identical to those shown and described in connection with FIG. 1 except that, in place of the mechanical pump 25, the control system of FIG. 2 has an aspirating pump 31 located at the juncture of the tubes 21, 22 and 23. The aspirating pump 31 is shown in further detail in FIG. 3. In this aspirating pump 31, the tube 21 leads to a converging section 32 and the tube 22 leads from a diverging section 33. Between the converging section 31 and the diverging section 33, there is a short restricted venturi passage 34. The tube 23 leading from the lower end of the sump 19 is connected into the short restricted passage 34. Thus, the venturi pump 31, as illustrated in FIG. 3, creates a venturi effect in the known manner, with the reduction in pressure of the refrigerant vapor that flows through the restricted passage 34 creating a suction that draws liquid refrigerant from the sump 19 through the tube 23. Since the venturi pump 21 depends upon the flow of refrigerant vapor to create the "pumping" suction flow of liquid refrigerant, no liquid refrigerant flows through the compressor when the compressor 11 stops during an off cycle.

FIG. 4 illustrates a combined sump and head pump 36 that may be substituted for both the sump 19 and the pump 25 of FIG. 1. The tube 18 leading from the evaporator is connected through an opening 37 at the upper end of the combined sump and head pump 36. The tube 23 is connected directly to the suction side of the compressor 11 and it has a vertical section 38 that extends through an opening 39 in the bottom of the combined sump and head pump 36 and thence upwardly. The upper end 40 of the tube section 38 is open and is well above the level of liquid within the sump and head pump 36 so that only vapor can enter the open end 40. There is a small orifice 41 through the side of the tube section 38. The small orifice 41 is positioned below the level of liquid within the sump and head pump 36. The orifice 41 is sized to meter a desired constant rate of flow of liquid into the tube section 38 to be mixed with the vapor therein. Hence, the rate of flow of liquid through the small orifice 41 is a function of the size of the orifice, and flow is produced by virtue of the liquid head within the sump and head pump 36. As before, the liquid level sensor 27 senses variations in the level of liquid within the sump and head pump 36 and transmits these sensed variations by the control means 28 to control operation of the expansion valve 13.

FIGS. 5 and 6 illustrate two ways in which the expansion valve 13 may be controlled by a liquid level sensor. In FIG. 5, the liquid level sensor 27 includes a high electrical contact probe 44 that is located within the sump 19 to be contacted by the liquid within the sump only when the liquid has risen to a predetermined high value, and a low electrical contact probe 45 that is submerged within the bath of liquid within the sump 19 and is always in contact with the liquid. The high probe 44 is connected by a conductor 46 through a solenoid coil 47 to one side 48 of a power supply. The low probe 45 is connected through a conductor 49 to the other side 50 of the power supply. The solenoid coil 47 has the usual connection 51 to alternately open and close the expansion valve 13.

When the liquid level within the sump 19 is below the high probe 44, the circuit that includes the solenoid coil 47 is open and the coil 47 is deenergized. When the coil 47 is deenergized, the valve 13 is open to permit refrigerant to circulate through the evaporator 14. When the liquid level within the sump 19 rises to contact the probe 44, as a result of excess supply of refrigerant to the evaporator 14, the circuit to the solenoid coil 47 is closed. When the coil 47 closes, the valve 13 closes, interrupting the flow of refrigerant to the evaporator 14. With the flow of refrigerant to the evaporator 14 interrupted, liquid from the sump 19 is gradually pumped by the pump 25 at a controlled rate of flow for mixture with the vapor that flows from the upper end of the sump through the tube 21. When the liquid level again drops below the upper probe 44, the circuit to the solenoid coil 47 is again broken, and the expansion valve 13 is again opened to admit refrigerant to the evaporator 14.

FIG. 6 illustrates another form of liquid level sensor 27 for controlling operation of the expansion valve 13. In FIG. 6, the expansion valve 13 has a housing 54 with an internal wall 55 separating the interior housing into an inlet chamber 56 and an outlet chamber 57. A valve passage 58 through the wall 55 establishes communication between the inlet chamber 56 and the outlet chamber 57. The tube 16 extends through the housing 54 to deliver refrigerant to the inlet chamber 56. The tube 17 extends through the housing 57 to withdraw refrigerant from the outlet chamber 57. A valve member 59 is movable toward and away from the valve passage 58 to block or vary the rate of flow of refrigerant through the valve passage 58. The housing 54 is mounted to and extends upwardly from the sump 19.

A float 60 within the sump 19 rises and falls with rising and falling of the liquid level within the sump 19. A rod 61 is connected between the float 60 and the valve member 59 to cause the valve member 59 to follow movement of the float 60. There may be a suitable bellows 63 connected to the sump 19 and to the rod 61 to provide a liquid seal and reduce the friction of movement of the rod 61. The sidewalls of the bellows 63 are parallel to maintain a constant cross-sectional area the same as that of the valve passage 58. As a result, high pressure in the liquid inlet cavity 56 pushes upward on the valve member 59 and downward on the bellows 63 with the same force so upward and downward forces are balanced.

Normally, the valve member 59 is so positioned that refrigerant flows from the tube 16 to the valve opening 58 to the tube 17 and to the evaporator at a rate such that the rate of liquid refrigerant flowing from the evaporator to the sump via tube 18 is equal to the rate that liquid refrigerant is being pumped out of the bottom of the sump by the pump. However, if the load on the evaporator varies, varying the rate of evaporation of liquid, the amount of liquid remaining within the sump 19 will vary, causing the level of liquid within the sump 19 to change.

When the liquid level drops within the sump, the float 60 drops, drawing the valve member 59 further from the valve opening 58 and permitting more refrigerant to flow to the evaporator 14. When the liquid level within the sump 19 rises because of reduced load on the evaporator 14, the valve member 59 moves toward the valve opening 58, throttling the flow of refrigerant through the valve. If the liquid level within the sump 19 rises sufficiently high because of reduced load in the evaporator 14, the valve member 59 moves into contact with the wall 55, completely blocking the flow of refrigerant to the evaporator 14.

Thus, the systems shown in FIGS. 5 and 6 are examples of liquid level sensors for operating an expansion valve 13 in either open or closed positions or operating an expansion valve 13 through throttling positions between wide open and closed positions. In either case, the expansion valve is operated to control the rate of flow of refrigerant to the evaporator in response to and as a function of the rate of withdrawal of liquid from the sump 19. Of course, other controls for accomplishing the results of the controls of FIGS. 5 and 6 may be used.

What I claim is:

1. In a refrigeration system having a compressor, a condenser, an expansion valve and an evaporator connected in series by tube means, the expansion valve having an opening for the passage of refrigerant, a control for controlling the expansion valve to regulate the rate of flow of refrigerant to the evaporator comprising, a sump, tube means leading from the outlet side of the evaporator to the sump, the tube means being connected into the sump at a point to permit liquid refrigerant to fall to the lower end of the sump with vapor remaining in the upper end of the sump above the liquid level therein, tube means for supplying vapor from the upper end of the sump to the suction side of the compressor, a head pump for withdrawing liquid from the sump at a predetermined rate of flow, the pump comprising a tube having an open upper end positioned above the liquid level within the sump, the tube extending downwardly through the sump and having its other end connected to the suction side of the compressor, and a metering hole in the side of the tube, the metering hole being positioned within the sump below the liquid level therein, and means to vary the size of the expansion valve opening in response to variations in liquid level within the sump to control the rate of flow of refrigerant through the expansion valve.

2. The system of claim 1 wherein the means to vary the size of the expansion valve opening includes an element for al-

ternately throttling and enlarging the expansion valve opening in response to rising and falling of liquid within the sump.

3. In a refrigeration system having a compressor, a condenser, an expansion valve and an evaporator connected in series by tube means, the expansion valve having an opening for the passage of refrigerant, a control for controlling the expansion valve to regulate the rate of flow of refrigerant to the evaporator comprising, a sump, tube means leading from the outlet side of the evaporator to the sump, the tube means being connected into the sump at a point to permit liquid refrigerant to fall to the lower end of the sump with vapor remaining in the upper end of the sump above the liquid level therein, tube means for supplying vapor from the upper end of the sump to the suction side of the compressor, an aspirating pump for withdrawing liquid from the sump at a predetermined rate of flow, the aspirating pump including a venturi section in the tube means for supplying vapor from the upper end of the sump to the compressor, and tube means leading from the lower end of the sump to the venturi section, and means to vary the size of the expansion valve opening in response to variations in liquid level within the sump to control the rate of flow of refrigerant through the expansion valve.