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Bottum et al.

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[54] **VEHICLE AIR CONDITIONING SYSTEM**

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Related U.S. Application Data

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[52] **U.S. Cl.** **62/243,** 62/503
[51] **Int. Cl.** **F25b 43/00**
[58] **Field of Search** 62/243, 503, 511, 513

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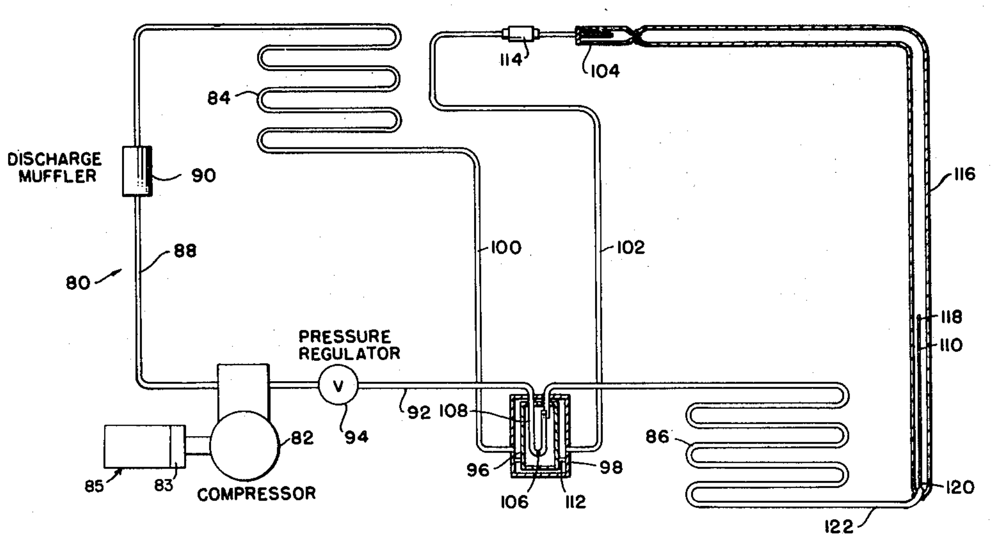
[57] **ABSTRACT**

The vehicle air conditioning system comprises the usual compressor, evaporator and condenser connected together in operative relationship. Capillary tube refrigerant expansion means are provided between the condenser and evaporator. A suction accumulator is provided between the evaporator and compressor so that the system will be effective when the compressor operates at variable speeds, the condenser is subjected to variable ambient temperatures and the evaporator is subjected to a variable load.

1 Claim, 2 Drawing Figures



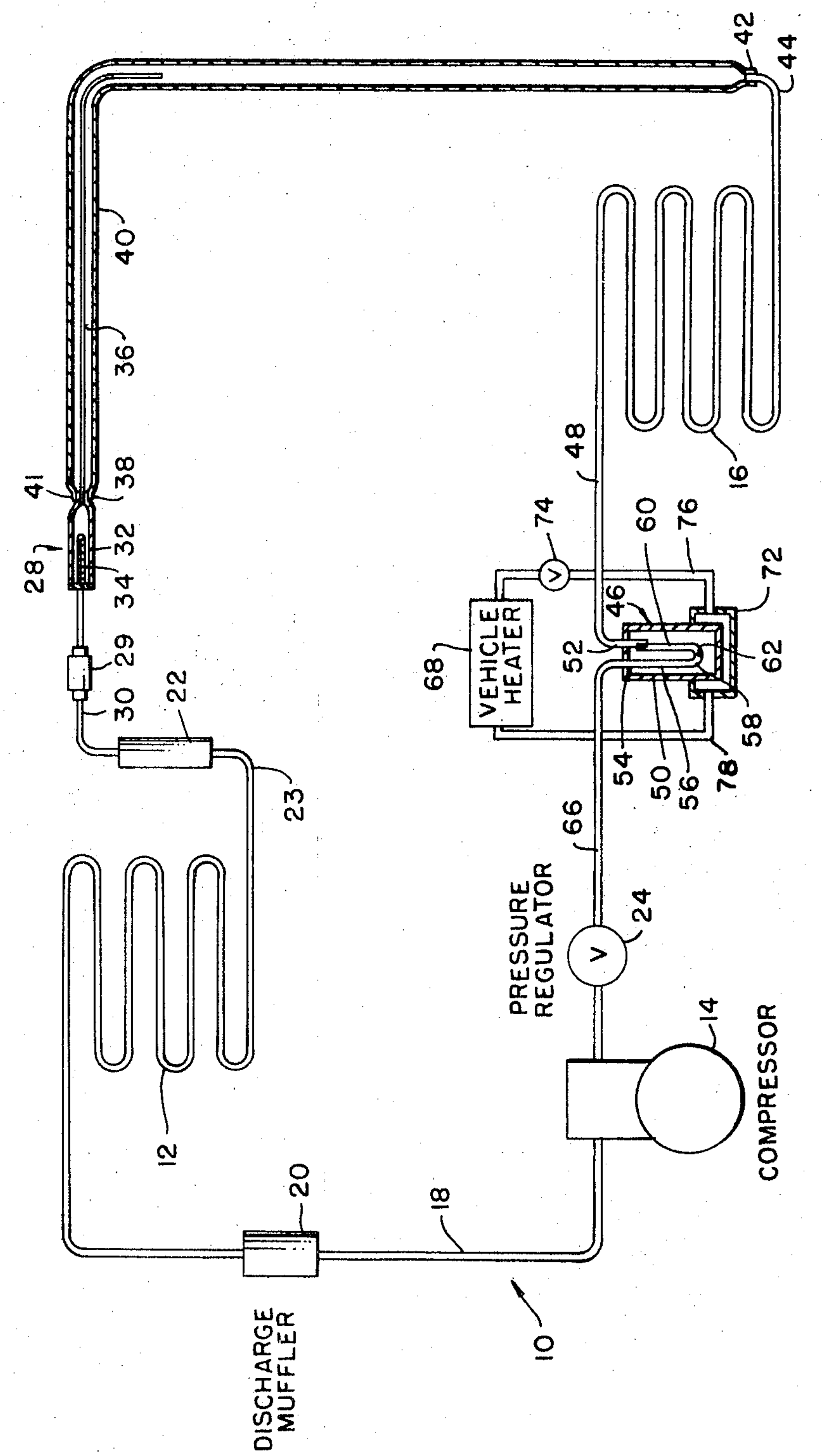

VEHICLE HEATER
PRESSURE REGULATOR
COMPRESSOR
DISCHARGE MUFFLER
V
10
12
14
16
18
20
22
23
24
28
29
30
32
34
36
38
40
41
42
44
46
48
50
52
54
56
58
60
62
66
68
72
74
76
78

FIG.1

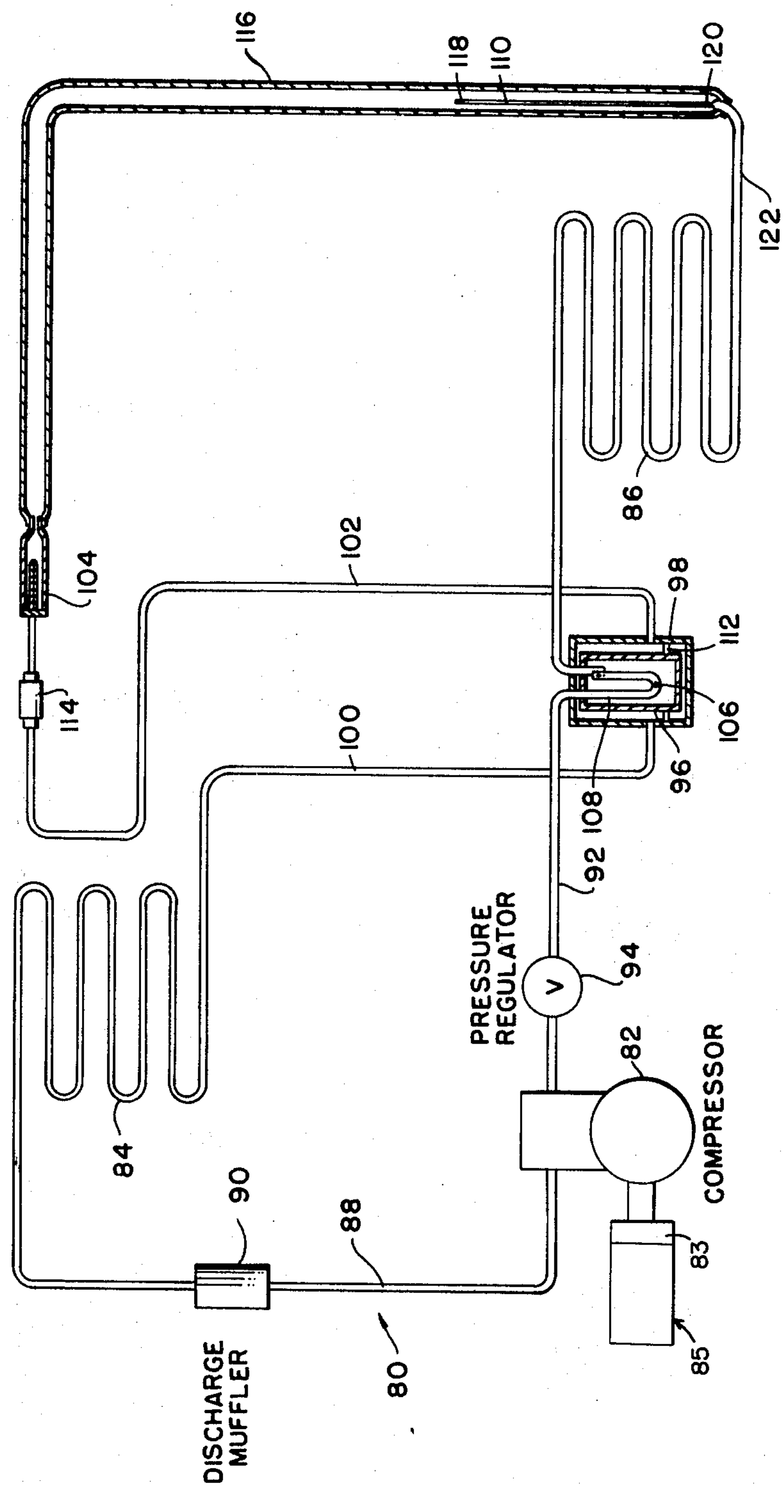

116
118
110
120
122
86
102
104
98
112
114
106
100
96
108
92
PRESSURE REGULATOR
V
94
82
COMPRESSOR
84
90
88
83
85
80
DISCHARGE MUFFLER

FIG. 2

VEHICLE AIR CONDITIONING SYSTEM

CROSS REFERENCE TO RELATED APPLICATION

This application is a division of application Ser. No. 841,032, filed July 11, 1969, now U.S. Pat. No. 3,766,748, issued Oct. 23, 1973.

BACKGROUND OF THE INVENTION

It has been common practice in automotive air conditioning systems to utilize an expansion valve, either of the thermostatic or automatic type, to provide expansion means for the liquid refrigerant from the high pressure side of the system to the low pressure side. Such expansion valve structures have several disadvantages. Firstly, they are relatively expensive. Additionally, because of the fact that such valves are manufactured of several moving parts, a maintenance cost is always present. Thermostatic expansion valves have a particular drawback in tending to "hunt". This results in the evaporator coil not being uniformly filled. This latter condition is particularly true when an evaporator pressure regulating valve is used on the suction side of the evaporator. Such expansion valves also require the use of the other components such as a liquid receiver between the condenser and evaporator. In some systems a muffler is used between the evaporator and compressor which adds to the overall cost of the system.

It has been previously suggested that the expansion valve be replaced with a capillary tube which would provide the desired expansion means. However, because of the conditions under which vehicle air conditioning systems are operated, it has not been practical in the past to use a capillary tube. The compressor of the vehicle system is driven by the vehicle engine which may operate at high or low speeds. Various devices may be used to provide a uniform speed for the compressor. However, such devices have not been completely satisfactory. Further, vehicle air conditioning systems must operate under variable ambient temperature and pressure conditions, either caused by change in location of the vehicle (as the vehicle, for example, is driven from a hot, low altitude location up a mountain to a cooler, higher altitude location.)

In accordance with the present invention, it has been found that it is possible to use a capillary tube as the expansion device if a suction accumulator is provided between the evaporator and the compressor. The use of a capillary tube is advantageous in the reduction in cost as the result of elimination of parts. Additionally, the capillary tube is more dependable than an expansion valve because it has no moving parts and therefore does not require adjustment or in other respects get out of order. The capillary tube also results in feeding the evaporator coil more uniformly because there is no opening and closing as in the case of a valve. As a result, the evaporator coil may be maintained full at all times and may, in fact, even spill over into the suction accumulator.

The use of a capillary tube instead of an expansion valve is advantageous in that the load on the vehicle engine of the air conditioning system is less at start-up due to the tendency for equalization of pressures by the capillary tube. This means that it requires less torque to start the engine. Also, if the air conditioning system is of the cycling type, there will be less vibration and shock as the compressor re-starts at the beginning of

each cycle because of pressure equalization resulting from the use of a capillary tube.

SUMMARY OF THE INVENTION

A vehicle air conditioning system is provided. The system comprises a compressor, an evaporator and a condensor connected in operative relationship. Capillary tube refrigerant means are provided between the condensor and evaporator. A suction accumulator is provided between the evaporator and compressor whereby the system effectively operates when the compressor operates at variable speeds, the condensor is subjected to variable ambient temperatures and the evaporator is subjected to a variable load. Preferably, the suction accumulator comprises a casing having an inlet and an outlet. A U-shaped tube forms the outlet. The bend in the tube is adjacent the bottom of the casing. A metering opening is provided in the bend of the tube to meter liquid refrigerant from the casing into the gas flowing through the U-shaped tube. The capillary tube is preferably mounted within a protective outer tube of larger diameter. The inlet to the capillary tube may be connected to the high pressure side of the system with the outlet within the protective tube. Alternately, the outlet of the capillary tube may be connected to the low pressure side of the system with the inlet to the capillary tube being within the protective tube.

In the drawings:

FIG. **1** is a schematic of one embodiment of a vehicle air conditioning system in accordance with the present invention; and

FIG. **2** is a schematic view of a second embodiment of a vehicle air conditioning system in accordance with the present invention.

Referring to FIG. **1**, it will be noted that the vehicle air conditioning system **10** comprises a condenser **12**, compressor **14**, and evaporator **16**. The outlet of the compressor **14** is connected to the inlet of the condenser **12** by a line **18**. A discharge muffler **20** is provided in line **18** to minimize the noise problem on the high pressure side of the system.

The outlet of the condenser **12** is connected to the inlet of a drier **22** via line **23**. The drier **22** is of the usual type and may contain, for example, silica-gel, for the removal of moisture from the refrigerant.

The outlet of the drier **22** is connected to the inlet of a strainer **28** via line **30**. The strainer **28** comprises a tubular container **32** which is provided with a cup-shaped inlet screen **34** to filter foreign particles from the sight A slight glass **29** is provided in line **30**.

A capillary tube **36** is directly connected to the outlet **38** of the container **32**. The capillary tube is essentially an expansion device. The length of the tube **36** depends upon the size of the particular condenser **12** used in the system and the particular type of refrigerant used. The inner diameter of the tube **36** is very small and the length may vary greatly from a few inches up to several feet depending upon the overall capacity of the system. Because the capillary tube offers a restricted passage, the resistance to the refrigerant flow is sufficient to build up a high enough head pressure to produce some condensation of refrigerant gas. Operating balance is obtained by properly proportioning the size and length of the tube to the particular system on which it is used.

The capillary tube **36** is received within a protective tube **40** of considerably greater diameter than the capillary tube. One end **41** of the tube **40** is directly mounted on the outlet of the strainer **28.** The other end **42** of the tube **40** is connected to a refrigerant line **44** which in turn leads to the inlet of the evaporator **16.** The tube **40,** of course, becomes filled with the refrigerant which exists from the capillary tube **36.** The refrigerant contained within the tube **40** may be considered to be at the low pressure side of the system because it has passed through the capillary tube **36.** As liquid refrigerant flows through the capillary tube **36,** the pressure is reduced and there is some conversion of liquid to gas. At the outlet of the capillary, there usually will be a discharge of both gaseous and liquid refrigerant. A single capillary tube is illustrated. However, a greater reduction of pressure from the capillary may be made by providing several shorter capillaries each feeding one pass of the evaporator coil **16.**

The outlet of the evaporator **16** is connected to the inlet of the suction accumulator **46** via line **48.** The suction accumulator **46** comprises a casing **50** having an inlet tube **52** which extends through the upper end and terminates within the casing in the upper portion thereof. An outlet tube **54** also extends through the upper end of the casing **50.** The outlet tube **54** is in the shape of a U-tube. One leg **56** of the tube **54** extends from the upper end of the casing downwardly to a point adjacent the lower end of the casing. The tube is then provided with a bend **58** and the second leg **60** extends upwardly and terminates in an open end adjacent to the upper end of the casing. A small metering opening **62** is provided in the tube bend **58** for the passage of metered amounts of liquid refrigerant from the casing into the tube **54.**

In operation of the accumulator **46,** cold refrigerant gas having some liquid refrigerant entrained therein enters the accumulator through the inlet tube **52.** The incoming gases, which move at a relatively high velocity, are directed downwardly and are free to expand. The refrigerant gases are drawn into the open end of the U-tube **54,** pass through both legs thereof and exit from the accumulator. The outlet of the accumulator **46** is connected to the inlet of the compressor **14** via line **66.** A pressure regulator valve **24** is provided in line **66.** The compressor, which creates a suction, draws the gaseous refrigerant through the accumulator at a relatively rapid rate.

Liquid refrigerant which enters the accumulator through the inlet tube **52** drops to the bottom of the accumulator and is subsequently drawn through the small opening **62** in the tube bend **58** and then through the leg **56** at a metered rate. The liquid which is drawn through the opening **62** is entrained in the stream of gaseous refrigerant and is drawn through the leg **60** and thence to the compressor of the system. The opening **62** acts as a restriction and causes liquid refrigerant to be metered into the compressor at a controlled rate. The accumulator thus acts to prevent large amounts of liquid refrigerant from suddenly entering the compressor. Such sudden surges of liquid may result in seriously damaging the compressor. The suction accumulator **46** also permits variation in the refrigerant charge throughout the cycle and thus efficient operation of the system at different speeds and ambient temperature conditions. The suction accumulator may also contain a desiccant which would eliminate the need for a separate drier **22.** The construction of the accumulator **46** results in the accumulator acting as a muffler. Thus, the usual muffler provided in the suction lines may be eliminated.

The accumulator **46** is placed in heat exchange relationship with the water of the vehicle heater **68.** As will be noted, the outlet of the heater **68** is connected to the inlet of a jacket **72** via line **76.** An on-off valve **74** is provided in this line. The jacket **72** encloses the lower portion of the suction accumulator **46.** The outlet of the jacket **72** is connected to the inlet of the heater **68** via line **78.**

Placing the accumulator **46** in heat exchange relationship with the vehicle heater water results in permitting the refrigeration system to be run continuously throughout the year. This eliminates the use of the usual magnetic clutch provided on vehicle air conditioning systems with a consequent cost saving. In the winter months, heat will be supplied to the refrigeration system via the heat exchange relationship above described. Consequently, the refrigeration system will be loaded even in the wintertime, thus allowing for return of oil to the compressor from the remainder of the system. This results in maintaining the compressor in good operating condition throughout the year because oil is prevented from logging in other parts of the system and starving the compressor of oil. Additionally, the heat exchange relationship assists in drying our liquid in the gas return to the compressor and thereby assists in preventing bearing washout of the compressor. The system becomes more loaded in cooler ambients as more hot water is used to provide heat to the car heater. In the warm ambients the heat exchanger will have no water through it as normally the water valve **74** will be shut.

The function of the evaporator pressure regulator valve **24** is to partially close when the pressure in the evaporator **16** begins to decrease. When the valve **24** partially closes, it causes the evaporator pressure to remain at a minimum pre-determined pressure which is selected so that the corresponding temperature thereof will not permit the evaporator to freeze. Freon-12 is the refrigerant most often used in vehicle air conditioning systems. This refrigerant will boil at 21.7°F. below zero at atmospheric pressure. In view of the fact that water freezes at 32°F., the temperature in the evaporator must be controlled so that water collecting on the core surface will not freeze and block air flow through the unit. In order to control the temperature, it is necessary to control the amount of refrigerant entering the evaporator and to control the pressure inside the evaporator. To obtain maximum cooling effects, the refrigerant must remain in the evaporator long enough to completely vaporize. If insufficient refrigerant is present in the evaporator, cooling efficiency decreases. The evaporator pressure regulator valve is used to provide the necessary refrigerant pressure control to aid in preventing evaporator freeze-up and to aid in maintaining efficiency of the system. The system may be designed for use without the valve **24.** However, the use of this valve is desirable to provide greater stability and protection against evaporator freeze-up and to eliminate the possible necessity of another control element in the system.

Operation of the refrigeration system **10** will now be described. Cool refrigerant gas is drawn from the accumulator **46** into the compressor **14** (which is driven by the vehicle engine) and pumped therefrom to the condenser **12** under high pressure. This high pressure gas will also have a high temperature as a result of being subjected to compression. As the gas passes through the condenser, it loses heat to the ambient atmosphere, the condenser usually being located at the forward portion of the vehicle in front of the automotive radiator to result in air passing thereover. The gas is thus condensed to a liquid. The liquid passes from the condenser **12** through the drier **22** and strainer **28** into the capillary tube **36.** Passage of the liquid through the capillary tube **36** results in reducing the pressure thereof and in partial conversion of a liquid to a gas. The refrigerant exists from the capillary tube **36** into the protective tube **40.** There is sufficient flow to normally flood the tube **40.** The tube **40** protects the capillary tube **36** from physical damage and also protects this tube from sudden temperature changes such as a hot blast of air from the vehicle engine which might influence its performance. The refrigerant then passes into the evaporator **16,** maintaining the evaporator in the most desired flooded condition throughout the cycle of operation. This is opposed to a system wherein an expansion valve is used. In such a system, the evaporator is not always maintained in the desired flooded condition because of hunting and seeking of the expansion valve. The refrigerant vaporizes within the evaporator. Normally, a motor driven fan is provided to blow air over the evaporator for cooling purposes within the vehicle.

Refrigerant gas exits from the evaporator into the suction accumulator **46.** This gas may have liquid refrigerant entrained therein and, in fact, liquid refrigerant may spill over lightly from the evaporator before vaporizing into the suction accumulator because of the high condition of flooding which the capillary tube **36** maintains. The gas is removed from the accumulator **46** immediately by the U-tube **54.** Liquid refrigerant is retained in the accumulator for the time necessary for it to be metered through the metering opening **62.** There is always a metering of refrigerant through the opening **62** regardless of temperature or pressure conditions within the system. Return of refrigerant to the compressor **14** does not depend upon, for example, heat exchange between the accumulator and a coil therearound containing hot liquid or gas. Thus, the system will function in a controlled manner regardless of the temperature conditions therewithin. Upon return of the refrigerant to the compressor, the cycle is repeated.

The system thus described includes many counterbalancing factors which permits it to be operated over a wide range of compressor speeds, ambient temperature conditions and load conditions. The capillary tube will satisfactorily control refrigerant flow from very low speeds to very high speeds. At higher speeds liquid may tend to back up in the condenser but is available because of the large volume of the suction accumulator. Consequently, the liquid will be further subcooled than is normal and will flow more rapidly through the capillary resulting in maintaining refrigerant flow throughout the system at the desired controlled rate. Another factor affecting the operation of the system at higher speeds is that the compressor volumetric efficiency falls off considerably thus providing an additional counterbalancing factor. The evaporator pressure regulator also will reduce refrigerant flow as it controls minimum evaporator pressure.

FIG. **2** illustrates another embodiment of the vehicle refrigeration system. The system **80** comprises a compressor **82,** condenser **84** and evaporator **86.** The outlet of the compressor **82** is connected to the inlet of the condenser **84** via line **88.** The compressor **82** is driven by the engine **83** of vehicle **85.** A discharge muffler **90** is provided in this line. The outlet of the evaporator **86** is connected to the compressor **82** via line **92.** An evaporator pressure regulator valve **94** is provided in this line as is a suction accumulator **96.** A jacket **98** is provided around the suction accumulator **96.** A line **100** leads from the outlet of the condenser **84** to the inlet of the jacket **98.** A line **102** leads from the outlet of the jacket **98** to a strainer **104.** Liquid refrigerant circulates through the jacket **98** in heat exchange relationship with the suction accumulator **96.** This heat exchange relationship assists in preventing flooding of liquid refrigerant to the compressor in that it aids in vaporizing the refrigerant therewithin so that less will pass through the metering opening **106** in the U-tube **108** and be directed to the compressor. Additionally, this heat exchange relationship permits the evaporator **86** to be run in a variable load super-heat condition. Because of the fact that the low side of the evaporator coil may be run in a completely flooded condition, the capacity of the evaporator will be increased to provide superior performance. Additionally, the liquid exiting from the condenser is sub-cooled prior to entering the capillary tube **110.** Alternately, a heat exchange coil connected to the condenser outlet may be provided within the suction accumulator **96.** Further, a tube may be brazed around the outside of the suction accumulator and be connected to the outlet of the condenser. It will be noted that a desiccant **112** is provided within the jacket **98** to remove moisture from the refrigerant. This eliminates the need for a separate drier at the inlet to the capillary tube **110.**

As previously discussed, the strainer **104** screens out foreign matter and prevents it from entering the capillary tube **110.** A sight glass **114** is provided just prior to the strainer to permit visual examination of the condition of the fluid therewithin.

A protective tube **116** is connected between the outlet of the strainer **104** and the inlet to the evaporator **86.** The tube **116** receives refrigerant directly from the strainer. The inlet end **118** of the capillary tube **110** is not connected directly to the strainer outlet as previously described in connection with FIG. **1.** The outlet end **120** of the capillary tube is connected to a line **122** which is then directed to the inlet of the evaporator. As a consequence, the refrigerant contained in the capillary tube **110** is at the low side pressure as opposed to the liquid within the capillary tube **36** which was at the high side pressure. This arrangement does not affect the basic operation of the system. However, depending upon the overall characteristics of the refrigeration system, in some instances, it may be desirable to connect the capillary tube as in FIG. **2** and in other instances as in FIG. **1.**

What we claim as our invention is:

1. In combination with a vehicle, an air conditioning system comprising a compressor, an evaporator and a condenser connected in operative relationship, said vehicle including an engine, said engine being drivingly connected to the compressor, capillary tube refrigerant expansion means between the condenser and evaporator, said capillary tube refrigerant expansion means comprising a capillary tube connected at one end to the low pressure side of the system leading to the evaporator, a protective tube of larger diameter around said capillary tube, one end of said protective tube being adjacent to the evaporator and being closed, the other end of said protective tube being connected to the high pressure side of the system adjacent to the condenser, said capillary tube terminating short of said other end, a suction accumulator between the evaporator and compressor whereby the system effectively operates when the compressor operates at variable speeds, the condenser is subjected to variable ambient temperatures, and the evaporator is subjected to a variable load, heat exchange means provided on said suction accumulator, said heat exchange means comprising a jacket around the suction accumulator and spaced therefrom to provide for flow of refrigerant therearound in heat exchange relationship therewith, and means connecting said heat exchange means between said condenser and capillary tube refrigerant expansion means to provide heat exchange between the refrigerant from the condenser and the refrigerant from the evaporator in the suction accumulator.

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