United States Patent

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[15] **3,651,657**

[45] ***Mar. 28, 1972**

[54] **AIR CONDITIONING SYSTEM WITH SUCTION ACCUMULATOR**

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[*] Notice: The portion of the term of this patent subsequent to Oct. 5, 1988, has been disclaimed.

[22] Filed: **Jan. 26, 1970**

[21] Appl. No.: **5,811**

[52] **U.S. Cl.** **62/196,** 62/217, 62/503
[51] **Int. Cl.** **F25b 1/00**
[58] **Field of Search** 62/196, 278, 217, 503

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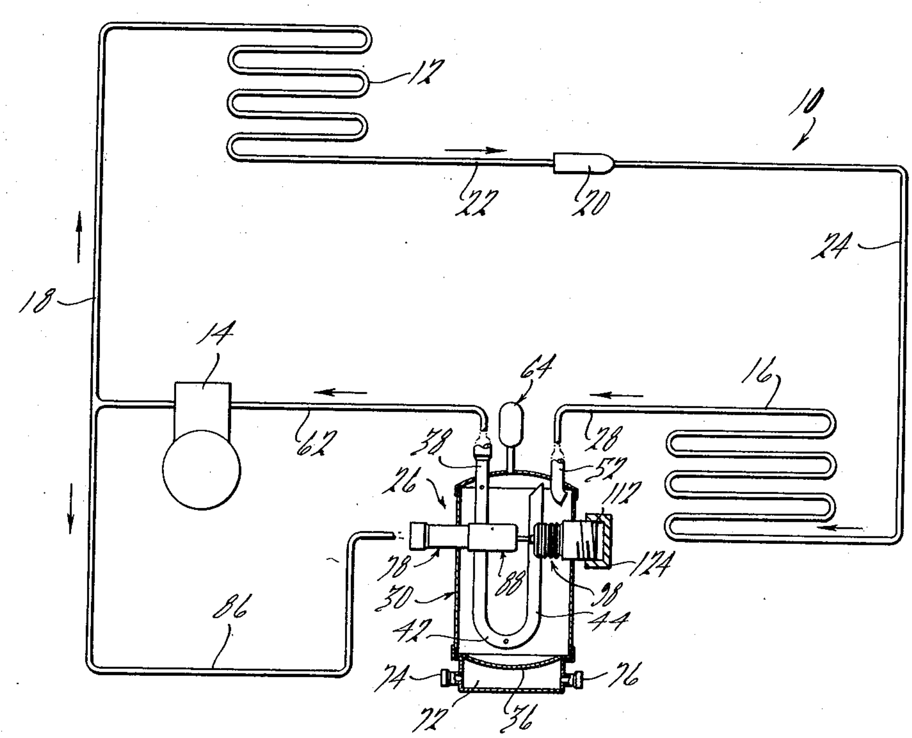
[57] **ABSTRACT**

A vehicle air conditioning system is provided. The 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. Bleedoff means from the output of the compressor are connected to the suction accumulator. Control means are provided for selectively injecting the relatively high pressure, high temperature gases of the compressor output into the accumulator to maintain the pressure within the accumulator at a substantially constant level.

8 Claims, 3 Drawing Figures



PATENTED MAR 28 1972 3,651,657

FIG. 1.

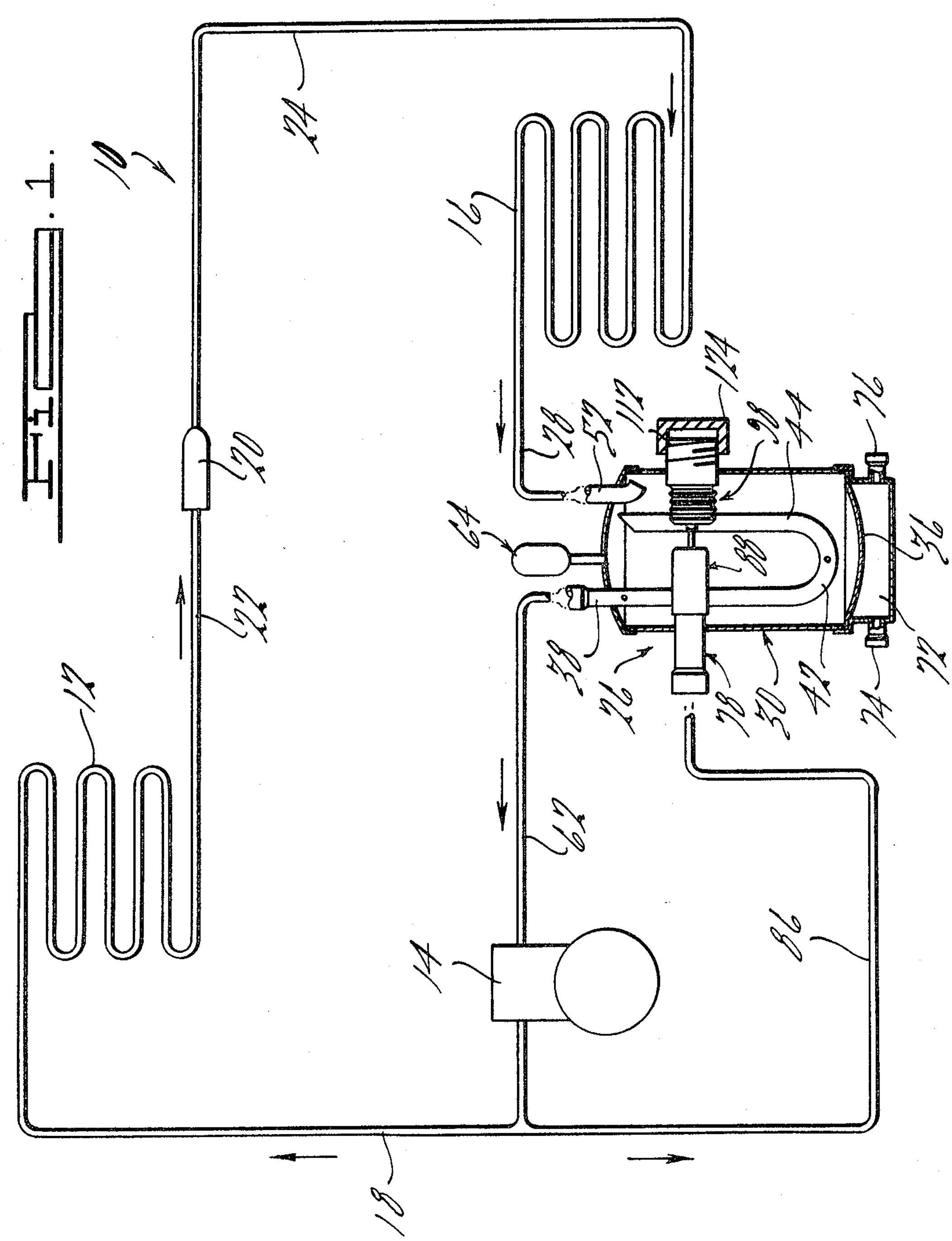


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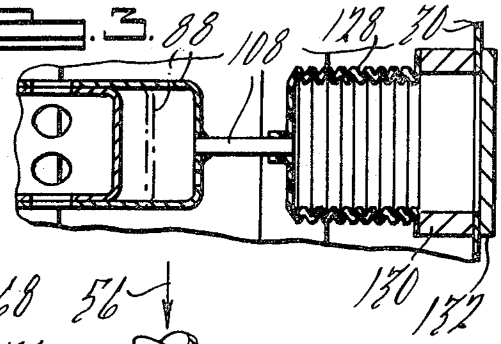
FIG. 3.



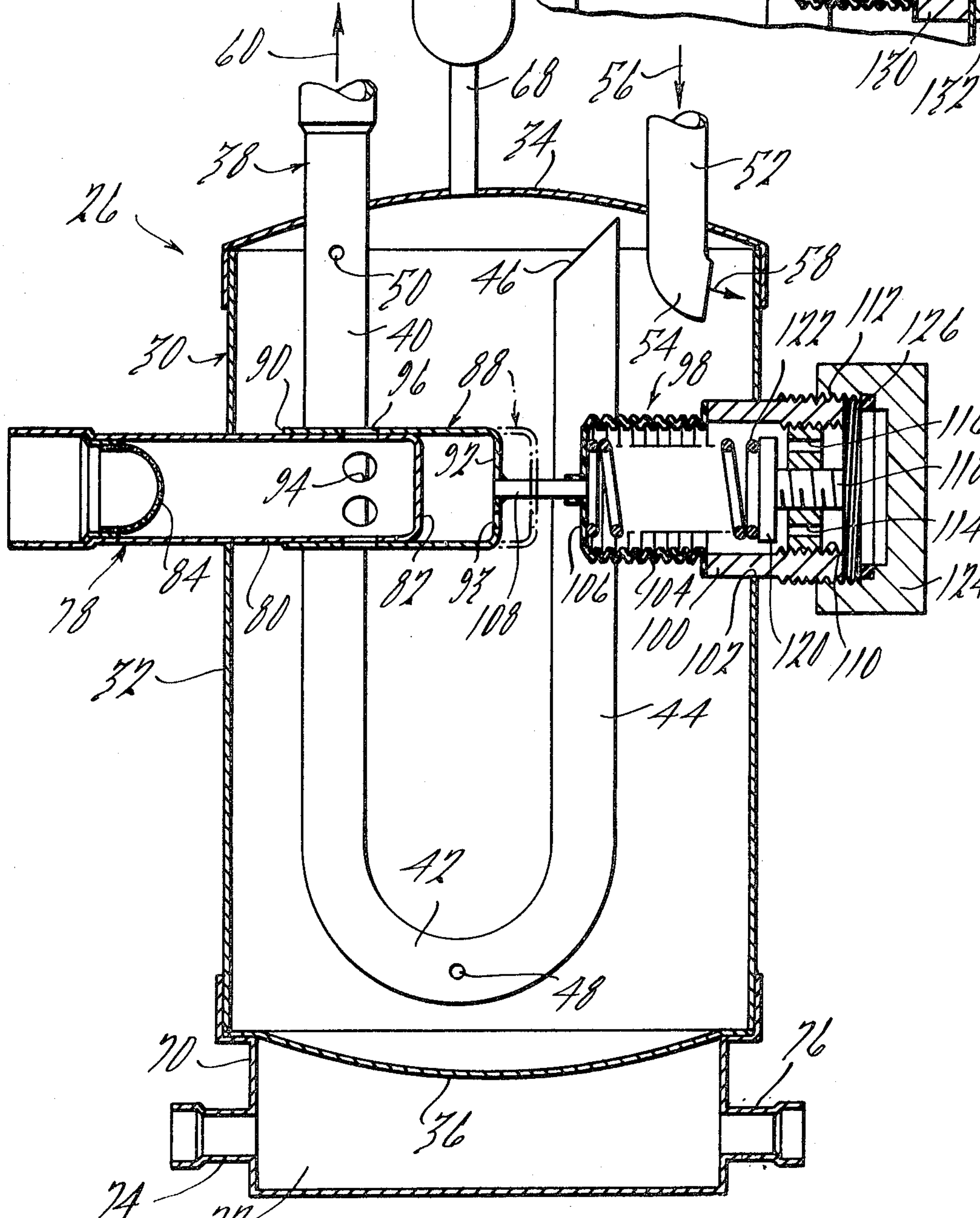


FIG. 2.

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AIR CONDITIONING SYSTEM WITH SUCTION ACCUMULATOR

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 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. Additionally, it has been found that if the pressure in the accumulator is controlled so that it is always maintained at a positive pressure and at a relatively uniform level, operation of the system may be improved and the use of an evaporator pressure regulator valve may be eliminated. To accomplish this, the accumulator is provided with control means for bleeding off a portion of the high pressure, high temperature gas from the compressor output and feeding it into the accumulator when necessary to maintain the accumulator pressure at the desired level. This results in a number of advantages as follows:

1. The cycling clutch usually used in an automotive air conditioning system may be eliminated because the hot gas bypass system for the accumulator provides capacity control and the compressor may therefore be run continuously even under "no load" conditions. This is particularly desirable on an automotive system because it is a known fact that compressors, particularly those having shaft seals, hold up better if they are allowed to run continuously thus keeping the seal covered with oil.

2. Maintenance of a uniform pressure in the accumulator protects the compressor components such as the compressor crankcase and seal and other parts of the system by preventing these components from being subjected to a vacuum.

3. The suction accumulator provides a convenient chamber for receiving hot bypass gas and tempering it with oil or liquid prior to its return to the compressor crankcase, and at the same time somewhat reducing the temperature of the hot bypass gas.

4. Maintaining the pressure in the suction accumulator substantially uniform (as for example, from 22 to 28 pounds in an R-12 system) prevents the evaporator from ever freezing.

SUMMARY OF THE INVENTION

A vehicle air conditioning system comprising a compressor, an evaporator and a condenser are connected in operative relationship. Capillary tube refrigerant expansion means are provided between the condenser and evaporator. A suction accumulator is connected between the output of the evaporator and the input of the compressor. A bleed-off connection extends between the output of the compressor and the accumulator. Control means are provided for selectively opening the bleed-off connection for injection of relatively high pressure output gases of the compressor into the accumulator to maintain the accumulator pressure substantially constant 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. The suction accumulator comprises a casing having a first inlet connected to the output of the evaporator and an outlet connected to the input of the compressor. A conduit is provided within the casing extending from a point adjacent the bottom of the casing to the casing outlet. This conduit acts as a suction tube to draw liquid from the casing and expel it into the casing outlet at a metered rate. A second inlet in the casing is connected to the aforementioned bleed-off connection. The control means comprises a valve on the second inlet. The valve includes a valve element movable to open and closed positions. A pressure or temperature sensitive valve element actuator is provided within the accumulator to move the valve element to the open position when the pressure in the accumulator falls below a pre-selected value and to move the valve element to a closed position when the pressure in the accumulator rises to a pre-selected value.

In the drawings:

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

FIG. 2 is an elevational view in section of the suction accumulator employed in the air conditioning system of FIG. 1; and

FIG. 3 is a view in section of a modified valve structure for use in conjunction with the accumulator of FIG. 2.

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 may be 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 strainer **20** via line **22**. The strainer **20** comprises a tubular container which is provided interiorly thereof with a cup-shaped inlet screen to filter foreign particles from the refrigerant. A drier containing a dessicant may be provided in line **22** for removal of moisture from the refrigerant.

A capillary tube **24** is directly connected to the outlet of the strainer **20** at one end and to the evaporator **16** at the other end. The capillary tube is essentially an expansion device. The length of the tube **24** depends upon the usual determining factors in a refrigeration system. The inner diameter of the tube is relatively small and the length may vary greatly from a few inches up to several feet depending upon the overall capacity of the system and the ID of the tube. Because the capillary tube offers a restricted passage, the resistance to refrigerant flow is sufficient to build up a high enough head pressure to produce condensation of refrigerant gas in the condenser over which air passes. 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 **24** may be received within a protective tube of larger diameter. The function of such a tube is to physically isolate the relatively delicate capillary tube from the environment to protect it from being inadvertently damaged. A single capillary tube is illustrated. However, as an option, several capillaries of the correct length may be used to individually feed each pass of the evaporator coil **16**. The outlet of the evaporator **16** is connected to the inlet of a suction accumulator **26** via line **28**.

DESCRIPTION OF THE PREFERRED EMBODIMENT

As illustrated in FIG. **2**, the suction accumulator **26** includes a casing **30** which comprises an open-ended tube **32** having an upper end closure **34** and a lower end closure **36** secured thereto as by brazing.

An outlet tube **38** extends through the upper end closure **34**. The outlet tube **38** is U-shaped. One leg **40** of the tube **38** extends downwardly to a point adjacent the lower end closure **36**. The tube is then provided with a bend **42** and a second leg **44** extends upwardly and terminates in an open end **46** adjacent the upper end closure **34**. A small metering opening **48** is provided in the tube bend **42**. Another opening **50** is provided in leg **40** at the upper end to equalize pressure in both of the legs **40, 44**.

The inlet tube **52** also extends through the upper end closure **34**. The inlet tube **52** extends for a short distance into the casing **30**. The lower end **54** is bent sidewardly so that the mouth thereof faces towards the surface of the casing interior approximately tangentially thereto and at a slight downward angle so that gases entering the inlet tube indicated by the arrow **56** exit from the tube as indicated by the arrow **58** in a direction generally tangential and at a downward angle with respect to the casing interior. As a consequence, the gases will follow a spiral path downwardly in the casing. This reduces turbulence within the casing which may cause frothing and splashing of any liquid which is contained therein.

In operation of the accumulator cold refrigerant gas having a small amount of entrained liquid refrigerant therein is received from the evaporator **16** and enters the accumulator through the inlet tube **52**. The incoming gases, which move at a relatively high velocity, are, as above described, directed tangentially against the inner surface of the casing and follow a spiral path downwardly of the casing interior. The gases are free to expand, with resultant reduction of the velocity thereof. As a consequence, incoming gases are not directed as a high-speed jet against any liquid which may be retained in the lower portion of the casing **30**.

The refrigerant gases which enter the casing are drawn into the open end **46** of the U-tube **38**, pass through both legs of the U-tube and exit via the leg **40** as indicated by the arrow **60**. The gases are passed from the U-tube **38** to the compressor **14** of the refrigeration system via line **62**. 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 opening **48** and thence through the leg **40** and out of the accumulator. It will be appreciated that the liquid which is metered into the leg **40** is entrained in the stream of gaseous refrigerant. It remains entrained in the gas as it passes from the accumulator and is drawn to the compressor of the system. The opening **48** 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.

During operation of the refrigeration system in which the accumulator **26** is installed, there are times when an unusual amount of refrigerant will collect in the accumulator. For example, when the system is shut off, such as is the case with an intermittently operated automotive air conditioning system, the refrigerant tends to collect in the evaporator and the accumulator. A similar situation may occur when the system is operated under low load conditions. The metering of the liquid refrigerant via the opening **48** results in liquid refrigerant being delivered to the compressor at a non-harmful rate.

The gaseous refrigerant which passes through the accumulator **26** is preferably subjected to the action of a drier to remove moisture therefrom. Illustratively, a drier **64** is mounted on the upper closure **34**. The drier **64** is of the type described in my copending application Ser. No. 795,827, filed Feb. 3, 1969. This drier comprises a casing **66** which encloses a desiccant material. A tube **68** extends from the casing **66** into connection with the closure **34**. The tube **68** provides fluid communication between the interior of the casing **30** and the casing **66**. Gases may flow into and out of the casing **66** via the tube **68**. When pressure is increased, gases tend to flow into the casing **66** and are subjected to the drying action of the desiccant. Upon a reduction of pressure in the casing **30**, gases will flow out of the casing **66** and pass to the compressor **14** via the U-tube **32**. Other types of driers may be used in place of the drier **64**. For example, a porous bag containing desiccant material may be directly mounted in the casing **30**.

The accumulator **26** is illustratively utilized for heat exchange in addition to its function as a suction accumulator. As will be noted, a jacket **70** defining a compartment **72** is secured to the lower end of the casing **30** in heat exchange relationship with the lower closure member **36**. An inlet **74** and outlet **76** are provided on the jacket **70**. A relatively warm fluid may be passed through the jacket **70**. For example, hot water from the vehicle heater may be passed therethrough. Alternately, the heat exchanger may be connected between the condenser **12** and evaporator **16**. Warm liquid refrigerant will then circulate through the jacket **70** in heat exchange relationship with the suction accumulator **26**. This heat exchange relationship will assist in preventing flooding of liquid refrigerant to the compressor in that it will aid in vaporizing the refrigerant therewithin so that less will pass through the metering opening **48**. Additionally, this heat exchange relationship will permit the evaporator to be run in a variable load superheat 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 subcooled, which is advantageous.

Referring now to the structure intermediate the ends of the casing **30**, it will be noted that an inlet tube **78** extends into one side of the casing. A portion **80** of the inlet tube **78** extends interiorly of the casing **30**. A closure **82** is provided on the inner end of the tube **78**. A perforated strainer or screen **84** is provided in the tube **78** to capture any foreign matter which may be entrained in gases entering the casing **30** via the tube **78**. The use of a strainer **84** is optional. The tube **78** is connected to the high pressure hot gas outlet of the compressor **14** via line **86** and bleeds off, at selected times, some of the high pressure hot gas emanating from the compressor.

A tubular valve element **88** is slidably received on the portion **80** of the tube **78**. One end **90** of the valve element **88** is open while the other end **92** is closed. A vent **93** is provided to equalize pressure in the valve element. A plurality of spaced apart openings **94** are provided around the periphery of the inlet tube portion **80** and spaced from the end closure **92**. Similar openings **96** are provided in the valve element **88** spaced from the end **90**. The openings **94, 96** may be placed in alignment with each other as illustrated in FIG. **2**. Upon movement of the valve element **88** to the right as viewed in FIG. **2**, and shown in dotted lines, the openings are moved out of registry. As a consequence, it will be appreciated that high pressure gases may flow into the casing **30** when the openings **94, 96** are in alignment and that flow of such high pressure gas is terminated upon movement of the valve element **88** to the dotted line position.

An actuator **98** is provided to move the valve element **88** to place the openings **94, 96** into and out of registry depending upon the pressure conditions prevailing within the casing **30**. The actuator **98** comprises a tubular member **100** which is mounted in an opening **102** in the side wall of the casing **30**. This mounting may be effected as, for example, by brazing. The tubular member **100** is open-ended. The inner end projects into the casing **30**. A resilient bellows **104** is mounted on the inner end of the tubular member **100**. The bellows **104** may be fabricated in the usual manner of metal or of a material such as rubber or plastic. The bellows is cup-shaped, the mouth being in registry with the tubular member **100** and secured thereto. The inner end **106** is closed. A plunger **108** extends from the inner end **106** into connection with the closed end **92** of the valve element **88**.

The exterior portion of the tubular member **100** is both internally threaded at **110** and externally threaded at **112**. An externally threaded support disk **114** is threaded into the tubular member **100**. A plurality of ports **116** are provided in the disk **114**. These ports provide fluid communication between the interior of the bellows **104** and the ambient atmosphere so that interior pressure in the bellows will be substantially atmospheric. The disk **114** has a central threaded opening which receives a screw **118**. A disk **120** is provided on the inner end of the screw **118**. A coil spring **122** is mounted within the bellows and extends between the inner surface of the end wall **106** and the disk **120**. The degree of compression of the spring **122** may be varied by threading the screw **118** into or out of the disk **114**. An internally threaded cap **124** is received on the external threads **112** of the tubular member **100**. A sealing element **126** is provided in the cap **124** to engage the tubular member **100** to substantially seal the inlet thereto. The main function of the cap **124** is to protect against ingress of foreign matter into the bellows construction.

The above-described high pressure hot gas inlet and associated valve structure may be termed a "hot gas bypass system." The function of the hot gas bypass system is basically to maintain the pressure within the casing **30** at a positive level and thereby prevent a negative pressure or vacuum from developing therewithin. Such a negative pressure is undesirable because of the connection of the outlet **38** with the inlet of the compressor **14**. By use of this system, the usual cycling clutch may be eliminated because the hot gas bypass system provides for capacity control and the compressor may therefore be run continuously. By use of the hot gas bypass system, suction pressure at the compressor is kept quite constant and at a positive level, not at a vacuum.

Operation of the hot gas bypass system will now be described. As will be appreciated, the pressure within the interior compartment defined by the bellows **104** is relatively constant for any given geographical area. Adjustments for different geographical areas and for different temperature conditions may be effected by manipulation of the adjusting screw **118**.

Consequently, assuming the bellows to be at equilibrium, the gas within the bellows will be compressed when the pressure within the casing **30** rises and will expand when the pressure within the casing **30** falls. Assuming a condition where a very low pressure approaching a vacuum develops within the casing **30**, the relatively higher pressure within the bellows and the spring **122** will cause the bellows to expand. Expansion of the bellows causes the valve element **88** to be shifted to the left as viewed in FIG. **2**. This brings the openings **94, 96** in registry allowing high pressure hot gas from the compressor outlet to enter the casing **30** via line **86**. This gas will cause the pressure within the casing **30** to rise. The rise of pressure will be accompanied by compression of spring **122** and contraction of the bellows with resultant movement of the valve element **88** to the right as viewed in FIG. **2** to the dotted line position. This will cause termination of incoming high pressure hot gases. As will be appreciated, the valve element **88** will be moved back and forth depending upon the pressure conditions prevailing within the casing **30** with the result that the pressure within the casing **30** will always be maintained at a relatively fixed value regardless of operating conditions of the overall system. This fixed value is preselected to be a positive pressure. The pressure level is determined by the physical characteristics of the bellows **104** and spring **122** and by the position of the adjusting screw **118**.

Alternate to the use of a bellows **104** wherein the interior of the bellows is at atmospheric pressure, a completely sealed bellows **128**, such as a bellows charged with Freon or other gas, as shown in FIG. **3**, may be used. Such a bellows may be either pressure sensitive or temperature sensitive, a temperature sensitive structure being illustrated. The temperature within the casing **30** is directly related to pressure conditions and therefore a charged temperature sensitive bellows is effective to control pressure within the casing **30**.

As will be noted, the bellows **128** is connected to a tubular member **130** mounted in an opening in the casing **30**, The outer end of the tubular **30**. **130** is sealed by a disk **132**.

The bellows **128** is connected to valve element **88** by the plunger **108**. Upon an increase in temperature, which means an increase in pressure in casing **30**, the bellows will expand as a result of expansion of the gas charge therein. This will cause the valve element **88** to move to the left, as shown in dotted lines, moving the inlet ports out of registry and preventing compressor gases from being injected into the casing **30**. Upon a decrease in temperature in casing **30**, the reverse will occur.

In similar fashion a bimetal element may be used to actuate the bypass valve.

Operation of the refrigeration system **10** will not be described. Refrigerant gas is drawn from the accumulator **26** 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. A portion of this high pressure, high temperature gas may be bled off to the accumulator **26** as previously described to maintain pressure within the accumulator at the desired level.

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 strainer **20** into the capillary tube **24**. Passage of the liquid through the capillary tube **24** results in reducing the pressure thereof and in partial conversion of liquid to a gas. The refrigerant exits from the capillary tube **24** 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 **26**. This gas may have liquid refrigerant entrained therein and, in fact, liquid refrigerant may spill over slightly from the evaporator before vaporization into the suction accumulator because of the high condition of flooding which the capillary tube **24** maintains. The gas is removed from the accumulator **26** immediately by the U-tube **38**. Liquid refrigerant is retained in the accumulator for the time necessary for it to be metered through the metering opening **48**. Any liquid refrigerant present is metered through the opening **48** 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 permit 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 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.

What I claim as my invention is:

1. A vehicle air conditioning system comprising a compressor, an evaporator and a condenser connected in operative relationship, capillary tube refrigerant expansion means between the condenser and evaporator, a suction accumulator connected between the output of the evaporator and the input of the compressor, a bleed-off connection between the output of the compressor and the accumulator, and control means for selectively opening said bleed-off connection for injection of relatively high pressure output gases of the compressor into the accumulator to maintain the accumulator pressure substantially constant 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.

2. A vehicle air conditioning system as defined in claim 1, and further characterized in that said suction accumulator comprises a casing having a first inlet connected to the output of the evaporator and an outlet connected to the input of the compressor, a conduit within the casing extending from a point adjacent the bottom of the casing to the casing outlet, said conduit acting as a suction tube to draw liquid from the casing and expel it into the casing outlet at a metered rate, a second inlet in the casing connected to said bleed-off connection, said control means comprising a valve on said second inlet, said valve including a valve element movable to open and closed positions, and a valve element actuator sensitive to one of pressure and temperature within the accumulator to move the valve element to the open position when the pressure in the accumulator falls below a preselected value and to move the valve element to a closed position when the pressure in the accumulator rises to a preselected value.

3. A vehicle air conditioning system as defined in claim 2, and further characterized in that said valve element actuator comprises a resilient bellows secured in the casing, the interior space of said bellows being sealed from the interior of the casing, said bellows being connected to the valve element whereupon expansion of the bellows will move the valve element to one position and contraction of the bellows will move the valve element to the other position.

4. A vehicle air conditioning system as defined in claim 3, and further characterized in the provision of a spring interiorly of the bellows, said spring biasing the bellows to move the valve element to the open position, interior pressure in said accumulator tending to cause collapse of the bellows and move the valve element to the closed position whereupon the valve element will be moved to the open or closed position depending upon pressure conditions within the accumulator casing.

5. A vehicle air conditioning system as defined in claim 4, and further characterized in the provision of a manually adjustable compression element in engagement with said spring, said compression element being adjustable to vary the force exerted by the spring against the bellows.

6. A vehicle air conditioning system as defined in claim 2, and further characterized in that said second inlet comprises a tubular member, a portion of said tubular member extending into the accumulator casing, the interior end of said tubular member being closed, the portion of said tubular member extending into the casing having opening means in the side wall thereof, said valve element comprising a tubular member slidably received on the portion of the second inlet tubular member extending into the accumulator casing, said valve element tubular member having opening means in the side wall thereof, said opening means of the valve element tubular member being in registry with the opening means in the inlet tubular member when the valve element is moved to the open position and being out of registry thereof when the valve element is moved to the closed position.

7. A vehicle air conditioning system as defined in claim 3, and further characterized in that said bellows defines a sealed space, said space being filled with a charge of a temperature sensitive gas which expands upon an increase of temperature thereby tending to close the valve and contracts upon a decrease in temperature thereby tending to open the valve.

8. A vehicle air conditioning system as defined in claim 1, and further characterized in the provision of heat exchange means on said suction accumulator, and means for connecting the heat exchange means with a source of warm fluid to provide for operation of the system in a continuously loaded condition.

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