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[54] **REFRIGERATION SYSTEM WITH HEAD PRESSURE CONTROL**

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[51] **Int. Cl.** **F25b 41/00**

[58] **Field of Search** 62/149, 174, 196

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[57] **ABSTRACT**

A receiver between the condenser and the flow control device in a refrigeration system stores liquid refrigerant under pressure which is fed through a check valve to the high pressure liquid refrigerant feed line upstream of the flow control device. A pressure regulation valve bypasses the check valve to permit high pressure liquid refrigerant to enter the receiver from the feed line when line pressure exceeds receiver pressure. A vapor flow control line fluid couples the receiver to the evaporator downstream of the flow control device and a pressure regulation valve in this line insures maintenance of proper pressure differential between the line and the receiver.

14 Claims, 2 Drawing Figures

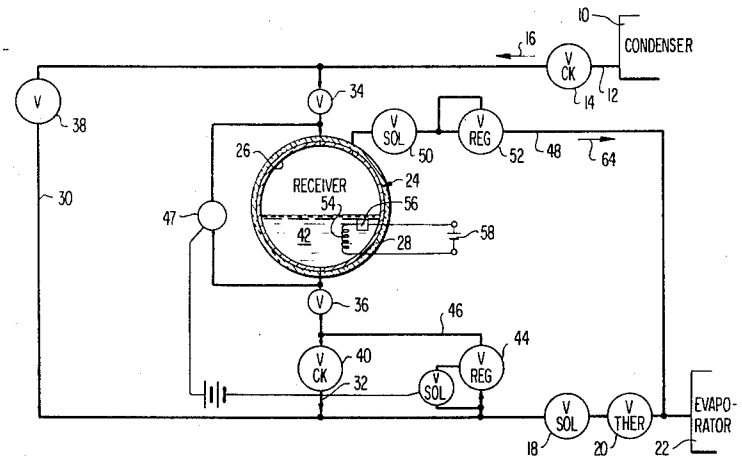
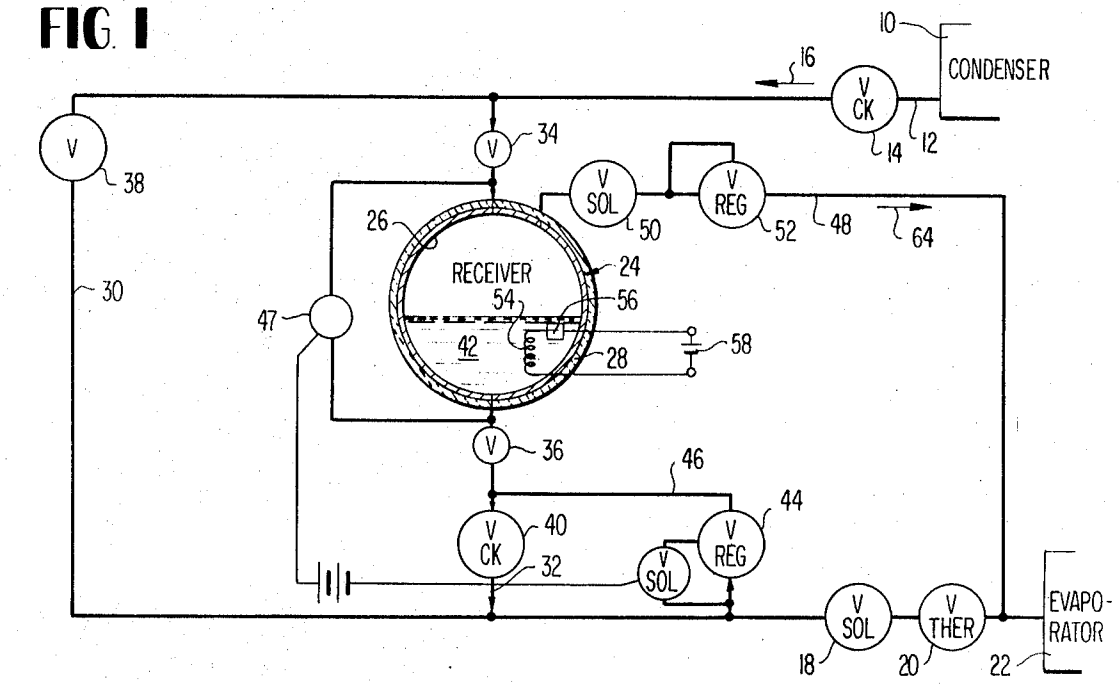


FIG. 1


10
CONDENSER
16
V CK
14
12
V
38
34
V SOL
50
V REG
52
48
64
26
RECEIVER
54
24
56
42
28
58
30
47
36
46
44
40
32
EVAPO-
RATOR
18
20
22

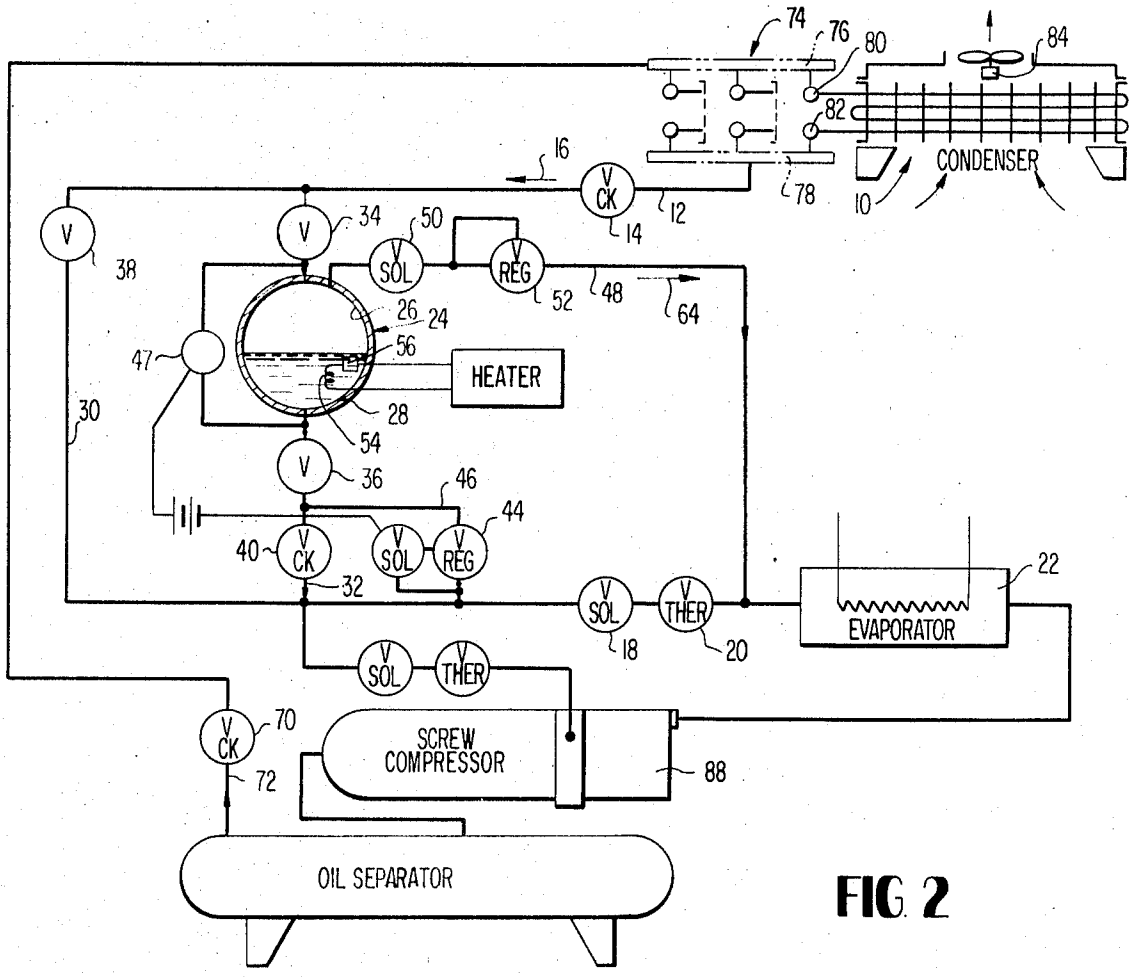

74
76
80
84
82
CONDENSER
78
10
16
CK
14
12
V
38
34
50
SOL
REG
52
48
64
26
24
56
47
HEATER
28
30
54
36
46
44
40
32
18
THER
20
EVAPORATOR
22
70
72
SCREW
COMPRESSOR
88
OIL SEPARATOR

FIG. 2

REFRIGERATION SYSTEM WITH HEAD PRESSURE CONTROL

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to refrigeration systems, and more particularly, to such systems wherein the condenser is air cooled and may be at the same or lower level than the evaporator.

2. Description of the Prior Art

In refrigeration systems employing an air cooled condenser, conventionally a rotary screw compressor or its equivalent compresses the refrigerant gas and delivers the same under pressure to a condenser where the gas is condensed and subcooled prior to expansion and passage through the evaporator, wherein cooling of the fluid surrounding the evaporator occurs by extraction of heat therefrom. The gas is leaving the evaporator or low side of the system, returns to the compressor for recompression prior to reaching the condenser for continued recirculation. In systems where the condenser is remote from the compressor and evaporator, and where the condenser is at the same or at a lower level than that of the evaporator, there exists the possibility of refrigerant vapor entrainment in the liquid refrigerant being fed from the condenser to the flow control device upstream of the evaporator, if the liquid is not adequately subcooled, and/or as a result of a liquid line pressure drop and/or an elevation difference between the condenser and evaporator. Vapor entrainment in the liquid feed line not only causes improper refrigerant feed to the evaporator and thus results in erratic control of the refrigeration system, but further results ultimately in an overall reduction in system cooling capacity.

The liquid refrigerant flowing from the condenser to the flow control device upstream of the evaporator is normally subcooled by virtue of proper sizing of the condenser fin surface. Furthermore, sizing of the liquid line between components of the system avoids excessive pressure drop and the possibility of vapor entrainment. However, when the condenser is operating under low temperature ambient conditions, the heat rejection surface required to effect the desired condensing is necessarily reduced and the refrigerant pressure in the system is reduced. That is, the liquid refrigerant collects within the condenser passages and rises until the surface area of the heat exchange surface necessary to maintain the desired pressure within the system for the refrigerant being condensed, is sufficiently diminished, at which point, line pressure in the liquid line rises to adequately produce proper refrigerant flow. However, under some circumstances, there is insufficient refrigerant within the system to maintain system pressure in both the high pressure and the low pressure sides, the refrigeration effect at the evaporator is minimized, and the suction pressure to the compressor drops excessively. This may cause the control associated with the compressor to shut down the compressor such as is characteristic of systems being started at low ambient, without head pressure control.

Attempts have been made to store liquid refrigerant within a receiver so as to supply liquid refrigerant to the high pressure side of the system under low ambient temperature conditions, to eliminate these deficiencies.

It is to this end that the present invention is directed.

SUMMARY OF THE INVENTION

The present invention is directed to a refrigeration system which includes a compressor, a condenser and an evaporator, in that order, within a closed loop, with a high pressure liquid feed line coupling the condenser to the evaporator via a flow control device, and a low pressure vapor return line connecting the evaporator to the compressor inlet. The improvement provided by the present invention resides in a liquid refrigerant receiver fluid coupled to the high pressure liquid feed line upstream of the flow control device and downstream of the condenser, with a check valve between the receiver and the high pressure liquid line permitting flow of pressurized liquid refrigerant from the receiver when the liquid refrigerant line pressure is below a predetermined value but prevents reverse flow. A pressure regulating valve bypasses the check valve to permit high pressure liquid refrigerant to enter the receiver for storage whenever the liquid refrigerant line pressure exceeds a given value. A vapor control line fluid couples the receiver, above the level of the liquid refrigerant, to the feed line downstream of the flow control device to relieve vapor pressure within the receiver. A second pressure regulator valve carried by the vapor line insures vapor flow to the evaporator under certain predetermined vapor pressure conditions within the receiver. A check valve between the condenser and the receiver prevents the flow of liquid refrigerant to the condenser directly from the receiver. A bypass line is connected from the condenser to the flow control device and bypasses the receiver, and manual inlet and outlet valves to the receiver are provided to isolate the receiver from the system. Further, a manual valve within the liquid bypass line permits the bypass to be selectively coupled into the fluid circuit. A solenoid valve within the vapor control line selectively couples that line to the receiver, and a solenoid valve upstream of the flow control device permits isolation of the evaporator from the receiver and condenser. The receiver may be thermally insulated and may have an electrical heater within the same to vaporize the stored liquid refrigerant to maintain a minimum temperature and/or pressure in the receiver.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic view of a portion of a refrigeration circuit employing the refrigerant head pressure control of the present invention.

FIG. 2 is a schematic view of a complete rotary screw compressor driven refrigeration circuit incorporating another embodiment of the refrigeration head pressure control of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Reference to FIG. 1 illustrates schematically the application of the refrigerant head pressure control of the present invention, in one form, to a conventional refrigeration system employing an air cooled condenser which supplies high pressure liquid refrigerant via a liquid refrigerant feed line to an evaporator with only these two elements in addition to a flow control device of the system being illustrated. The other components of the refrigeration system, such as the compressor, are

not illustrated in this view, and it may take any conventional form; for instance, the compressor may be a reciprocating compressor or a rotary screw compressor, as desired. In this respect, the refrigeration system employs an air cooled condenser illustrated at **10** which discharges liquid refrigerant under pressure into the high pressure liquid feed line **12** under control of check valve **14.** Check valve **14** operates such that liquid refrigerant flows from the condenser only in the direction of the arrow **16** within line **12** and, conventionally, the high pressure liquid refrigerant feed line **12** delivers liquid refrigerant under control of solenoid valve **18** to a flow control device or expansion valve **20** which permits expansion of the liquid refrigerant within evaporator **22** downstream thereof, whereupon thermal energy is absorbed by the vaporization of the liquid refrigerant; removing heat from the fluid surrounding the evaporator coil. The evaporator may take the form of a chiller, that is, act to reduce the temperature of a liquid surrounding the evaporator coil, or may be employed in an air conditioning or refrigeration system in which room air flows across the evaporator coil to cool the same.

Normally, the liquid refrigerant flowing from the condenser to the flow control device **20** is sufficiently subcooled to prevent the entrainment of vapor within the same or development of vapor within the high pressure liquid refrigerant feed line **12** prior to expansion at valve **20.** Depending upon ambient conditions and the logging of liquid refrigerant within the condenser **10,** there is more or less possibility of vapor entrainment in the liquid refrigerant feed line **12** at flow control device **20.**

In this respect, the present invention is directed to the provision of a liquid refrigerant storage receiver **24** which is illustrated as being in the form of a cylindrical metal tank **26** surrounded by a given thickness of thermal insulation **28** and being positioned intermediate the condenser **10** and the flow control device **20.** In this respect, feed line **12** branches into two parallel passages. A liquid bypass line **30** bypasses the receiver **24** such that the receiver may be completely isolated from the refrigeration system if necessary. Receiver **24** is fluid coupled in the system by receiver feed line **32.** The receiver feed line **32** includes a manually operated inlet valve **34** between the condenser **10** and the receiver **24** and a manually operated outlet valve **36** between the receiver and the flow control device **20.** Further, the liquid bypass line **30** also includes a manually operated valve **38** which is normally open but which may be closed as desired to force all of the liquid refrigerant passing from the condenser to the flow control device **20** to pass through the receiver **24.**

A check valve **40** is fluid connected between the receiver **24** and the high pressure liquid refrigerant feed line **12.** Whenever the pressure within the receiver **24** is higher than the liquid refrigerant feed line pressure, the liquid refrigerant as at **42,** stored within the receiver is fed into line **12** to insure continued flow of liquid refrigerant to the flow control device **20** and thence to evaporator **22.** A solenoid operated pressure regulating valve **44** bypasses check valve **40** via check valve bypass line **46** with its pressure being set at a predetermined value so as to permit the bleeding of high pressure liquid refrigerant from the feed line **12** to receiver **24** for storage therein at a predetermined line pressure above refrigerant storage pressure within receiver **24.** Level control **47** set to maintain a predetermined maximum refrigerant level in the receiver will shut off valve **44** and prevent further refrigerant from entering receiver, by de-energizing the solenoid.

An additional element of the present invention relates to the means for insuring proper refrigerant vapor pressure within the receiver **24,** A vapor control line **48** which is connected to the system feed line **12** downstream of the flow control device **20** and upstream of evaporator **22** at one end, is connected at the other end to the receiver **24** above the level of the liquid refrigerant **42.** Within this line is provided a solenoid operated valve **50** and regulating valve **52** which permits this control feature to be selectively connected into the system; Solenoid valve **50** is activated by a pressure switch sensing receiver pressure. Regulating valve **52** is sensitive to receiver pressure and is set at a predetermined point below that of the line pressure-reducing valve **44** at the receiver outlet and thereby maintains a differential pressure between the high pressure liquid refrigerant feed line **12** which is fluid coupled to bypass line **30** and the receiver **24** and thereby permits refrigerant flow into the receiver as required. Additionally, while the receiver **24** may be insulated, uninsulated, heated or unheated, or any combination thereof, as required by the ambient temperature in which the receiver is located, it may be desirable to control receiver pressure in response to ambient by energization of an electric heating coil **54** within the receiver by operation of a thermostatic switch **56** coupling the coil **54** to a source of electrical current as at **58** to maintain a preset receiver temperature.

In operation, the system is set up such that the receiver **24** is provided with a given volume of refrigerant maintaining a level of liquid refrigerant as at **42** and wherein the liquid bypass line **30** is opened by opening manually operated valve **38.** The receiver is cut off from the condenser by closing the manually operated receiver inlet valve **34.** The manually operated receiver outlet valve **36** is opened and flow to and from the receiver and the high pressure liquid refrigerant feed line **12** is under control of the check valve **40,** the pressure regulator valve **44** and level control **47,** while the vapor pressure within the receiver is under control of the vapor line pressure regulating valve **52** set to open below the pressure required to open valve **44.** Solenoid valves **50** and **18** are energized to open position. Assuming warm ambient conditions for air cooled condenser **10,** all of the excess refrigerant in the system will flow into the receiver through the pressure regulating valve **44** at a pressure above the set point of the regulating valve **44** in the receiver outlet until the predetermined refrigerant level in the receiver is reached.

As ambient temperature falls and flooding or logging of the condenser occurs, the refrigeration system demands more refrigerant and as a result the liquid pressure in line **12** will be reduced. When the pressure in line **12** decreases below receiver pressure, refrigerant will flow through check valve **40** into feed line **12** upstream of the flow control device **20,** thus making up the refrigerant charge necessary to keep the system full.

As the ambient again increases and the logged refrigerant is pushed out of the condenser due to the increase in discharge pressure of the condenser, it will flow through the liquid bypass line **30,** and through check valve bypass line **46,** via pressure regulation valve **44**

and level control **47**, into the receiver **24**. When the head pressure reaches the predetermined set point of the pressure regulating valve **44**, further, the vapor flow control line **48** coupled to the top of the receiver will maintain a proper differential for flow into the receiver under this condition even though the receiver **24** is subjected to a room ambient higher than saturated condensing pressure. Valve **50** through pressure regulating valve **52** will relieve the pressure within receiver **24**, the which case, vapor will escape as indicated by arrow **64** through line **48** to the feed line **12** downstream of the flow control device **20**. Under continued operation, the proper operating charge will be maintained in the system, automatically under all varying conditions of ambient temperature.

During a start up condition, when the ambient temperature is lower than the receiver temperature, the liquid stored in the receiver will be at a pressure sufficiently high to allow feeding of refrigerant to the evaporator via flow control device **20** and subsequent logging of the condenser until the liquid refrigerant fills a portion of the condenser to the extent of building sufficient head pressure for normal operation regardless of the ambient temperature that the condenser **10** is being subjected to. It is to be remembered, that for proper feed control, a minimum refrigerant pressure is required at the inlet to the flow control device **20** and further that when the compressor delivering the high pressure refrigerant gas to the condenser stops, refrigerant pressures tend to approach the level equivalent to ambient temperature under the arrangement of the present invention as exemplified in FIG. **1**. The head pressure control of the present invention maintains positive liquid refrigerant feed to the flow control device **20** at all times regardless of ambient conditions to which the condenser **10** is subject. The system insures total liquid refrigerant with minimum or no vapor entrainment at the inlet to the flow control device. The quantity of refrigerant adequate for the circulation needs, regardless of ambient, is readily achieved by storing excess liquid refrigerant in the receiver automatically while permitting the removal therefrom as needed in a completely automatic manner contingent upon ambient conditions. Flow of refrigerant to and from the receiver, modulated automatically, assures proper operation of both the condenser and evaporator heat exchangers.

The embodiment of FIG. **1** may be modified under certain ambient temperatures by eliminating check valve **14** which will cause the liquid refrigerant under pressure in the receiver to rapidly log the condenser during the off cycle. By using a time delay low pressure cutout, the system can be started and sufficient liquid pressure will be obtained within a relatively short period of time to provide proper system operation.

FIG. **2** shows an alternate form of the invention as applied to a multiple condenser refrigeration system employing a screw compressor as the means for compressing the refrigerant gas. The head pressure control for the refrigeration system of FIG. **2** is essentially the same as that of FIG. **1**. Like elements to the system of the embodiment of FIG. **1** are given like numerical designations in the illustrated embodiment of FIG. **2**. In this case, a screw compressor **88** discharges the compressed refrigerant gas at compressor outlet into the high pressure compressor discharge line **72** which fluid couples the screw compressor **88** to a plurality of air cooled condensers, such as condenser **10** via condenser manifold **74** including an inlet manifold passage **76** and an outlet manifold passage **78**. Tap point **80** delivers the high pressure gas from the screw compressor **88** to condenser **10**, and tap point **82** returns subcooled liquid refrigerant to outlet manifold **78**. Other condensers (not shown) are coupled to the other tap points of manifold **74**. A powered blower as at **84** permits forced air to pass over the condenser coil **86** condensing the refrigerant gas and subcooling the same prior to discharging the refrigerant or liquid into the high pressure liquid refrigerant feed line **12**. A compressor discharge check valve **70** prevents reverse flow to compressor **88**.

In all respects, the system of FIG. **2** operates in the identical manner to that of FIG. **1**.

While the invention has been particularly shown and described with reference to a preferred embodiment thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit, and scope of the invention.

What is claimed is:

1. In a closed loop refrigeration system including, in order, a compressor, a condenser and an evaporator and having a refrigerant circulating therebetween under control of a flow control device in the high pressure liquid refrigerant feed line coupling the condenser to the evaporator, the improvement comprising:

a liquid refrigerant receiver, a conduit fluid coupling said receiver to said liquid feed line upstream of said flow control device and downstream of said condenser,

a check valve within said conduit between said receiver and said feed line for permitting liquid refrigerant flow from said receiver feed line when said feed line pressure is below that of said receiver but preventing reverse flow, and

a pressure regulation valve bypassing said check valve and fluid connected between said receiver and said feed line downstream of said condenser and upstream of said flow control device to permit high pressure liquid refrigerant to enter said receiver from said feed line to charge said receiver.

2. The refrigeration system as claimed in claim **1**, further comprising a vapor flow control line fluid coupling said receiver to said feed line downstream of said flow control device and having a pressure regulating valve therein to relieve receiver vapor pressure to said feed line downstream of said flow control device.

3. The refrigeration system as claimed in claim **2**, further comprising an electrical heating element positioned within said receiver for vaporizing stored liquid refrigerant to increase refrigerant pressure within said receiver, means for energizing said electrical heating element, and means responsive to the temperature of the stored refrigerant within said receiver for selectively connecting said electrical heating element to said energizing means.

4. The refrigeration system as claimed in claim **2**, further comprising: means responsive to the level of liquid refrigerant within said receiver for controlling said pressure regulation valve.

5. The refrigeration system as claimed in claim **1**, wherein said liquid refrigerant receiver is additionally fluid coupled to said liquid refrigerant feed line between said condenser and said flow control device by means of a second conduit upstream of said first con-

duit, said feed line bypasses said first and second conduits, said receiver and said check valve, and a normally closed manually operated valve is interposed between said condenser and said receiver in said second conduit to prevent liquid refrigerant from entering the receiver other than through said pressure regulation valve.

6. The refrigeration system as claimed in claim **5**, further comprising an electrical heating element positioned within said receiver for vaporizing stored liquid refrigerant to increase refrigerant pressure within said receiver, means for energizing said electrical heating element, and means responsive to the temperature of the stored refrigerant within said receiver for selectively connecting said electrical heating element to said energizing means.

7. The refrigeration system as claimed in claim **1**, wherein said liquid refrigerant receiver is additionally fluid coupled to said liquid refrigerant feed line between said condenser and said flow control device by means of a second conduit upstream of said first conduit, said feed line bypasses said first and second conduits, said receiver and said check valve, and a normally closed manually operated valve is interposed between said condenser and said receiver in said second conduit to prevent liquid refrigerant from entering the receiver other than through said pressure regulation valve.

8. The refrigeration system as claimed in claim **7**, further comprising: means responsive to the level of liquid refrigerant within said receiver for controlling said pressure regulation valve.

9. The refrigeration system as claimed in claim **1**, further comprising an electrical heating element positioned within said receiver for vaporizing stored liquid refrigerant to increase refrigerant pressure within said receiver, means for energizing said electrical heating element, and means responsive to the temperature of the stored refrigerant within said receiver for selectively connecting said electrical heating element to said energizing means.

10. The refrigeration system as claimed in claim **1**, further comprising: means responsive to the level of liquid refrigerant within said receiver for controlling said pressure regulation valve.

11. In a closed loop refrigeration system including, in order, a compressor, a condenser and an evaporator and having a refrigerant circulating therebetweeen under control of a flow control device in the high pressure liquid refrigerant feed line coupling the condenser to the evaporator, the improvement comprising:

a divided flow path within said liquid refrigerant feed line upstream of said flow control device and downstream of the condenser,

a receiver positioned within one of said flow paths and including a normally closed, manually operated inlet valve positioned intermediate said condenser and said receiver for selectively isolating said receiver from said condenser,

a check valve intermediate said receiver and said feed line and within said one flow path for permitting liquid refrigerant flow from said receiver to said feed line when said feed line pressure is below that of said receiver but preventing reverse flow,

a pressure regulation valve bypassing said check valve and fluid connecting said feed line upstream of said flow control device to said receiver to permit high pressure liquid refrigerant to enter said receiver from said feed line to charge the same in response to feed line pressure above a predetermined value,

said second flow path comprising a liquid refrigerant feed line bypass about said receiver and said check valve,

normally open manual control valve means carried within said second flow path for selectively isolating said condenser from said flow control device, and

a vapor flow control line fluid coupling said receiver to said feed line downstream of said flow control device, and a regulating valve within said vapor flow control line to relieve vapor pressure within said receiver to said system downstream of said flow control device.

12. The closed loop refrigeration system as claimed in claim **11**, further comprising an electric heater positioned within said receiver, an electrical energy source, and a normally open thermostatic switch responsive to low temperature conditions within said receiver for connecting said energy source to said heater to maintain a pressure differential between said receiver and said liquid refrigerant feed line.

13. The closed loop refrigeration system as claimed in claim **11**, further comprising: means responsive to the level of liquid refrigerant within said receiver for controlling said pressure regulation valve.

14. The closed loop refrigeration system as claimed in claim **12**, further comprising: means responsive to the level of liquid refrigerant within said receiver for controlling said pressure regulation valve.

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