

Charge Management in Refrigerant Vapor Compression Systems

Field of the Invention

[0001] This invention relates generally to refrigerant vapor compression systems and, more particularly, to effective refrigerant charge management in refrigerant vapor compression systems, including transport refrigeration refrigerant vapor compression systems using carbon dioxide refrigerant and operating in a transcritical cycle.

Background of the Invention

[0002] Refrigerant vapor compression systems are well known in the art and commonly used in transport refrigeration applications for refrigerating air supplied to a temperature-controlled cargo space of a truck, trailer, container or the like for transporting frozen or perishable items. Refrigerant vapor compression systems are also commonly used in commercial refrigeration installations associated with supermarkets, convenience stores, restaurants, and other commercial establishments for refrigerating air supplied to a cold room or a refrigerated display merchandiser for storing frozen or perishable food items. Refrigerant vapor compression systems are also commonly used for conditioning air to be supplied to a climate-controlled comfort zone within a residence, office building, hospital, school, restaurant or other facility. Typically, such refrigerant vapor compression systems include a compressor, an air-cooled or water-cooled refrigerant heat rejection heat exchanger which functions as a condenser in subcritical operation and as a gas cooler in transcritical operation, a refrigerant heat accepting heat exchanger, which functions as an evaporator, and an expansion device, commonly a thermostatic or electronic expansion valve, disposed upstream, with respect to refrigerant flow, of the heat accepting heat exchanger and downstream of the heat rejection heat exchanger. These basic refrigerant system components are interconnected by refrigerant lines in a closed-loop refrigerant circuit, arranged in accord with known refrigerant vapor compression cycles.

[0003] Traditionally, most of these refrigerant vapor compression systems operate at subcritical refrigerant pressures. Refrigerant vapor compression systems operating in the subcritical range are commonly charged with conventional fluorocarbon refrigerants such as, but not limited to, hydrochlorofluorocarbons (HCFCs), such as R22, and more

commonly hydrofluorocarbons (HFCs), such as R134a, R410A and R407C. In today's market, greater interest is being shown in "natural" refrigerants, such as carbon dioxide, for use in air conditioning applications, commercial refrigeration applications, and transport refrigeration applications, instead of HFC refrigerants. However, because carbon dioxide has a low critical temperature, most refrigerant vapor compression systems charged with carbon dioxide as the refrigerant are designed to operate in the transcritical pressure regime, at least for a portion of their operation. For example, transport refrigerant vapor compression systems having an air-cooled refrigerant heat rejection heat exchanger operating in environments having ambient air temperatures in excess of the critical temperature point of carbon dioxide, 31.1 °C (88°F), must also operate at a compressor discharge pressure in excess of the critical point pressure for carbon dioxide, 7.38 MPa (1070 psia) and therefore will operate in a transcritical cycle. In refrigerant vapor compression systems operating in a transcritical cycle, the refrigerant heat rejection heat exchanger operates as a gas cooler rather than a condenser and operates at a refrigerant temperature and pressure in excess of the refrigerant's critical point temperature and pressure, while the evaporator operates at a refrigerant temperature and pressure in the subcritical range.

[0004] On the low-pressure side of the refrigerant vapor compression system, that is the portion between the outlet of the evaporator expansion device and the refrigerant suction inlet to the compression device, the refrigerant pressure and refrigerant temperature remain coupled. However, in transcritical operation, on the high-pressure side of the refrigerant vapor compression system, that is the portion between the refrigerant discharge outlet of the compression device and the inlet to the evaporator expansion device, the refrigerant pressure and refrigerant temperature are independent of each other. Consequently, refrigerant pressure can be optimized for only a single design operating point. Therefore, at off-design conditions, the refrigerant vapor compression system operation may be sub-optimal as the refrigerant charge will be either higher or lower than the optimal refrigerant charge at those conditions.

[0005] U.S. Patent Application Publication No. US/2005/0132729 A1 discloses a transcritical refrigerant vapor compression system having a refrigerant storage vessel containing a variable mass of refrigerant, whereby the capacity of the system may be

controlled. In a disclosed embodiment, the refrigerant storage vessel is in open fluid communication at all times through a single fluid line with a closed-loop refrigerant circuit at a location upstream, with respect to refrigerant flow, of the evaporator expansion device and downstream, with respect to refrigerant flow, of the refrigerant heat rejection heat exchanger. The mass of refrigerant within the refrigerant storage vessel is controlled through regulation of the temperature of the tank or regulation of the storage volume within the tank, which requires an additional measurable amount of power provided to a refrigerant system on a permanent or temporary basis.

Summary of the Invention

[0006] In an aspect of the invention, a refrigerant vapor compression system includes a refrigerant compression device, a refrigerant heat rejection heat exchanger, an expansion device, and a refrigerant heat absorption heat exchanger disposed in serial refrigerant flow communication in a closed-loop refrigerant circuit, a refrigerant storage device defining a storage volume connected by at least one refrigerant line in fluid communication with the closed-loop refrigerant circuit, and a flow control device interdisposed in the at least one refrigerant line. The flow control device has an open position wherein refrigerant may flow through the at least one refrigerant line and a closed position wherein refrigeration is blocked from flowing through the at least one refrigerant line. In an embodiment, a controller may be operatively associated with the flow control device for selectively positioning the flow control device in either an open position or in a closed position.

[0007] In an embodiment, the storage volume of the refrigerant storage device is connected by a single refrigerant line in fluid communication with the closed-loop refrigerant circuit at a location on a high-pressure side of the refrigerant vapor compression system upstream, with respect to refrigerant flow, of the expansion device, which is disposed in the closed-loop refrigerant circuit downstream of the refrigerant heat rejection heat exchanger and upstream of the refrigerant heat absorption heat exchanger. In an embodiment, the storage volume of the refrigerant storage device is connected by a single refrigerant line in fluid communication with the closed-loop refrigerant circuit at a

location on a low-pressure side of the refrigerant vapor compression system downstream, with respect to refrigerant flow, of the expansion device.

[0008] In an aspect of the invention, a refrigerant vapor compression system includes a refrigerant compression device, a refrigerant heat rejection heat exchanger, an expansion device, and a refrigerant heat absorption heat exchanger disposed in serial refrigerant flow communication in a closed-loop refrigerant circuit, and a refrigerant storage device defining a storage volume having an upper zone and a lower zone, with the upper zone connected by a first refrigerant line in fluid communication with said closed-loop refrigerant circuit at a location on a high-pressure side of the refrigerant vapor compression system upstream, with respect to refrigerant flow, of the expansion device, and the lower zone connected by a second refrigerant line in fluid communication with the closed-loop refrigerant circuit at a location on a low-pressure side of the refrigerant vapor compression system downstream, with respect to refrigerant flow, of the expansion device. A first flow control device interdisposed in the first refrigerant line and a second flow control device interdisposed in the second refrigerant line. Each of the flow control devices has an open position and a closed position. In an embodiment, each of the flow control devices may be a solenoid valve having an open position and a closed position. The refrigerant vapor compression system may further include a controller operatively associated with each of the first and second flow control devices for selectively positioning one of the first and second flow control devices in an open position and simultaneously selectively positioning the other of the first and second flow control devices in a closed position.

[0009] In an aspect of the invention, a method is provided for managing refrigerant charge in a refrigerant vapor compression system operating in a transcritical cycle, the refrigerant vapor compression system having a refrigerant compression device, a refrigerant heat rejection heat exchanger and a refrigerant heat absorption heat exchanger disposed in serial refrigerant flow communication in a closed-loop refrigerant circuit, with an expansion device disposed in the closed-loop refrigerant circuit downstream of the refrigerant heat rejection heat exchanger and upstream of the refrigerant heat absorption heat exchanger. The method includes the steps of: selectively withdrawing refrigerant from the closed-loop refrigerant circuit of the refrigerant vapor

compression system; storing the withdrawn refrigerant; and returning the withdrawn refrigerant from storage to the closed-loop refrigerant circuit of the refrigerant vapor compression system.

[0010] If the refrigerant storage device is connected to the closed-loop refrigerant cycle at location on a high-pressure side, then the refrigerant is typically withdrawn from the closed-loop refrigerant cycle during operation of the refrigerant vapor compression system and returned to the closed-loop refrigerant cycle during an off-cycle of the refrigerant vapor compression system. In this embodiment of the method, refrigerant is withdrawn from the closed-loop refrigerant circuit at a location on a high-pressure side upstream of the expansion device and the withdrawn refrigerant is also returned to the closed-loop refrigerant circuit at a location upstream of the expansion device.

[0011] If the refrigerant storage device is connected to the closed-loop refrigerant cycle at location on a low-pressure side, then the refrigerant is typically withdrawn from the closed-loop refrigerant cycle during an off-cycle of the refrigerant vapor compression system and returned to the closed-loop refrigerant cycle during operation of the refrigerant vapor compression system. In this embodiment of the method, refrigerant is withdrawn from the closed-loop refrigerant circuit at a location on a low-pressure side downstream of the expansion device and the withdrawn refrigerant is also returned to the closed-loop refrigerant circuit at a location downstream of the expansion device.

[0012] If the refrigerant storage device is connected to the closed-loop refrigerant cycle at two locations, one on a high-pressure side and the other on a low-pressure side, then the refrigerant is typically withdrawn from the closed-loop refrigerant cycle during operation of the refrigerant vapor compression system and returned to the closed-loop refrigerant cycle also during operation of the refrigerant vapor compression system. In this embodiment of the method, refrigerant is withdrawn from the closed-loop refrigerant circuit at a location on a high-pressure side upstream of the expansion device and the withdrawn refrigerant is returned to the closed-loop refrigerant circuit at a location on a low-pressure side downstream of the expansion device.

Brief Description of the Drawings

[0013] For a further understanding of the invention, reference will be made to the following detailed description of the invention which is to be read in connection with the accompanying drawing, where:

[0014] Figure 1 is a schematic diagram illustrating a first exemplary embodiment of a refrigerant vapor compression system in accord with the invention;

[0015] Figure 2 is a schematic diagram illustrating a second exemplary embodiment of a refrigerant vapor compression system in accord with the invention; and

[0016] Figure 3 is a schematic diagram illustrating a third exemplary embodiment of a refrigerant vapor compression system in accord with the invention.

Detailed Description of the Invention

[0017] Referring now to FIGs. 1-3, the refrigerant vapor compression system 10 includes a compression device 20, a refrigerant heat rejection heat exchanger 40, a refrigerant heat absorption heat exchanger 50, also referred to herein as an evaporator, connected in a closed-loop refrigerant circuit in series refrigerant flow arrangement by various refrigerant lines 2, 4 and 6. Additionally, an expansion device 55, operatively associated with the evaporator 50, is interdisposed in refrigerant line 4 downstream, with respect to refrigerant flow, of the refrigerant heat rejection heat exchanger 40 and upstream, with respect to refrigerant flow, of the refrigerant heat absorption heat exchanger 50. In the embodiments of the refrigerant vapor compression system 10 depicted in FIGs. 1-3, the expansion device 55 comprises an electronic expansion valve. However, it is to be understood that the expansion device may instead comprise a thermostatic expansion valve, or a fixed orifice device, such as a capillary tube.

[0018] When the refrigerant vapor compression system 10 is operating in a transcritical cycle, such as for instance when charged with carbon dioxide refrigerant and operating at a compressor discharge pressure in excess of the critical pressure point of carbon dioxide, the refrigerant heat rejection heat exchanger 40 operates at supercritical pressure and functions as a refrigerant gas cooler, but does not operate to condense the carbon dioxide refrigerant vapor. The tube bank 42 of the heat rejection heat exchanger 40 may comprise, for example, a plate fin and round tube bank, such as a tube bank of a

conventional round tube and plate fin heat exchanger or a corrugated fin and multi-channel flat tube bank of a minichannel or microchannel heat exchanger. In traversing the refrigerant heat rejection heat exchanger 40, the refrigerant passes through the heat exchanger tubes of the tube bank 42 in heat exchange relationship with a secondary fluid, typically ambient air, generally outdoor air, being drawn through the tube bank 42 by an air mover 44, such as one or more fans, operatively associated with the tube bank 42 of the heat rejection heat exchanger 40.

[0019] Whether the refrigerant vapor compression system 10 is operating in a subcritical cycle or a transcritical cycle, the refrigerant heat absorption heat exchanger 50, being located in the refrigerant circuit downstream, with respect to refrigerant flow, of the expansion device 55, always operates at a subcritical pressure and functions as an evaporator. In traversing the heat absorption heat exchanger 50, the refrigerant passes through the heat exchanger tubes of the tube bank 52 in heat exchange relationship with air to be conditioned, typically air at least partially drawn from and to be returned to a climate-controlled environment, being drawn through the tube bank 52 by an air mover 54, such as one or more fans, operatively associated with the tube bank 52 of the heat absorption heat exchanger 50, whereby the air is cooled and the refrigerant is evaporated and typically superheated. The tube bank 52 of the refrigerant heat absorption heat exchanger 50 may comprise, for example, a finned tube heat exchanger, such as for example a plate fin and round tube bank of a conventional round tube and plate fin heat exchanger, or a corrugated fin and multi-channel flat of a minichannel or microchannel heat exchanger.

[0020] The compression device 20 functions to compress and circulate refrigerant through the refrigerant circuit as will be discussed in further detail hereinafter. The compression device 20 may be a single, single-stage compressor as depicted, such as for example a scroll compressor, a reciprocating compressor, a rotary compressor, a screw compressor, or a centrifugal compressor. However, it is to be understood that the compression device 20 may also be a multiple-stage compression device having at least a lower pressure compression stage and a higher pressure compression stage with refrigerant flow passing from the lower pressure compression stage to the higher pressure compression stage. In such an embodiment, the multiple-stage compression device may

comprise a single, multi-stage compressor, such as, for example, a scroll compressor, or a screw compressor having staged compression pockets, or a reciprocating compressor having at least a first bank of cylinders and a second bank of cylinders, or a pair of single-stage compressors connected in series refrigerant flow relationship with the discharge outlet of the upstream compressor connected in serial refrigerant flow communication with the suction inlet of the downstream compressor. The compression device 20 may also comprise two or more compressors operating in a parallel or tandem configuration.

[0021] The refrigerant vapor compression system 10 further includes a refrigerant storage device 60, also referred to as a receiver, defining a volume wherein a variable refrigerant charge may be stored. The receiver 60 is in fluid flow communication with the closed-loop refrigerant circuit of the refrigerant vapor compression system 10 through at least one refrigerant line. The refrigerant vapor compression system 10 further includes a controller 100 operatively associated with a refrigerant flow control device interdisposed in the at least one refrigerant line connecting the receiver 60 in fluid flow communication with the closed-loop refrigerant circuit of the refrigerant vapor compression system 10. Refrigerant flow through the at least one refrigerant line is controlled by the selective opening and closing of the refrigerant flow control device interdisposed therein.

[0022] Referring now to FIG. 1, in the embodiment depicted therein, the receiver 60 defines a volume having a lower zone 63 wherein liquid refrigerant may be collected and an upper zone 67 wherein refrigerant vapor may reside. It is to be understood that, at certain environmental and operating conditions, the entire internal volume of the receiver 60 may be filled with the refrigerant vapor. The upper zone 67 is in refrigerant flow communication through a refrigerant line 12 with the refrigerant line 4 on the high-pressure side of the refrigerant vapor compression system 10, that is at a location downstream, with respect to refrigerant flow, of the refrigerant heat rejection heat exchanger 40, and upstream, with respect to refrigerant flow, of the refrigerant expansion device 55. The lower zone 63 is in refrigerant flow communication through a refrigerant line 14 with the refrigerant line 4 on the low-pressure side of the refrigerant vapor compression system 10, that is at a location downstream, with respect to refrigerant flow,

of the refrigerant expansion device 55, and upstream, with respect to refrigerant flow, of the refrigerant heat absorption heat exchanger 50. Additionally, a refrigerant flow control device 65 having an open position and a closed position is interdisposed in refrigerant line 12 and a refrigerant flow control device 75 having an open position and a closed position is interdisposed in refrigerant line 14. It is to be understood that any other locations on a high-pressure side and low-pressure side with the refrigerant vapor compression system 10 may be selected to provide refrigerant flow communication with the receiver 60.

[0023] In this embodiment, the controller 100 is operatively associated with each of the respective refrigerant flow control devices 65 and 75 interdisposed in refrigerant lines 12 and 14, respectively, to selectively position each of the respective refrigerant flow control devices in an open or a closed position. The controller 100 adjusts the amount of the refrigerant charge circulating through the closed-loop refrigerant circuit, defined by the refrigerant lines 2, 4 and 6, as necessary to maintain at desired refrigerant discharge pressure from the compression device 20 for a particular operating point, by selectively positioning the flow control devices 65 and 75 between their respective open and closed positions either to pass refrigerant from the closed-loop refrigerant circuit into the receiver 60, thereby reducing the amount of the refrigerant charge circulating through the closed-loop refrigerant circuit, or pass refrigerant from the receiver 60 into the closed-loop refrigerant circuit, thereby increasing the amount of the refrigerant charge circulating through the closed-loop refrigerant circuit. Thus, addition of refrigerant into the closed-loop refrigerant circuit occurs on the low-pressure side of the refrigerant vapor compression system 10, but removal of refrigerant from the closed-loop refrigerant circuit occurs on the high-pressure side of the refrigerant vapor compression system 10.

[0024] To remove refrigerant from the closed-loop refrigerant circuit of the refrigerant vapor compression system 10, typically during operation, the controller 100 positions the refrigerant flow control device 65 in its open position and positions the refrigerant flow control device 75 in its closed position. With the refrigerant flow control devices 65 and 75 so positioned, high pressure refrigerant vapor flows from the refrigerant line 4 through the refrigerant line 12 into the upper zone 67 of the storage

chamber of the receiver 60, but can not flow out of the receiver 60 through the refrigerant line 14 because the refrigerant flow control device 75 is in its closed position.

[0025] To add refrigerant to the closed-loop refrigerant circuit of the refrigerant vapor compression system 10, which can be done during operation or during an off-cycle, the controller 100 positions the refrigerant flow control device 65 in its closed position and positions the refrigerant flow control device 75 in its open position. With the refrigerant flow control devices 65 and 75 so positioned, refrigerant flows from the lower zone 63 of the storage chamber of the receiver 60 through the refrigerant line 14 into the refrigerant line 4, but high pressure refrigerant vapor can not enter the receiver 60 because the refrigerant flow control device 65 is in its closed position, thereby blocking the flow of high-pressure refrigerant vapor through the refrigerant line 12. It is to be understood that during off-cycle at certain environmental conditions, the refrigerant may be added to or removed from the close-loop refrigerant circuit of the refrigerant vapor compression system 10 though the refrigerant flow control devices 65 and 75.

[0026] The storage chamber of the receiver 60 will have an equilibrium pressure that varies with the amount of refrigerant stored therein, but, during operation of the refrigerant vapor compression system 10, is always less than the high-pressure side refrigerant pressure in the refrigerant line 4 upstream of the evaporator expansion device 55 and greater than the low-pressure side refrigerant pressure in the refrigerant line 4 downstream of the evaporator expansion device 55. During operation of the refrigerant vapor compression 10, removal of refrigerant from the closed-loop refrigerant circuit into the receiver 60 may be carried out by simply opening the refrigerant flow control device 65 for a period of time so that refrigerant vapor will flow through the refrigerant line 12 due to the pressure differential between the refrigerant pressure at the location at which the refrigerant line 12 taps into the refrigerant line 4 upstream of the evaporator expansion device 55 and the equilibrium pressure within the storage chamber of the receiver 60. During operation of the refrigerant vapor compression 10, addition of refrigerant into the closed-loop refrigerant circuit from the receiver 60 may be carried out by simply opening the refrigerant flow control device 75 so that refrigerant will flow through the refrigerant line 14 due to the pressure differential between the equilibrium pressure within the storage chamber of the receiver 60 and the refrigerant pressure at the

location at which the refrigerant line 14 taps into the refrigerant line 4 downstream of the evaporator expansion device 55.

[0027] It is to be understood that such refrigerant charge management is particularly important for transcritical operation of the refrigerant vapor compression system 10, since temperature and pressure of the refrigerant are independent from each other, and high-side optimum pressure would be different at each environmental conditions.

[0028] Referring now to FIG. 2, in the exemplary embodiment of the refrigerant vapor compression system 10 depicted therein, the receiver 60, rather being connected in refrigerant flow communication with both the high-pressure side and the low-pressure side of the refrigerant vapor compression system 10, is connected in refrigerant flow communication with the closed-loop refrigerant circuit on the high-pressure side only through a single refrigerant line 16 tapping into the refrigerant line 4 at location downstream of the refrigerant heat rejection heat exchanger 40 and upstream of the evaporator expansion valve 55. A refrigerant flow control device 85 having an open position and a closed position is interdisposed in the refrigerant line 16. The controller 100 is operatively associated with the refrigerant flow control device 85 to selectively position the refrigerant flow control device 85 in an open or a closed position.

[0029] In this embodiment, the controller 100 adjusts the amount of the refrigerant charge circulating through the closed-loop refrigerant circuit, defined by the refrigerant lines 2, 4 and 6, as necessary to maintain at desired refrigerant discharge pressure from the compression device 20 for a particular operating point, by selectively positioning the refrigerant flow control device 85 in its open position either to pass vapor refrigerant from the closed-loop refrigerant circuit into the receiver 60 or to pass refrigerant vapor from the receiver 60 back into the closed-loop refrigerant circuit, and in its closed position to block refrigerant flow through the refrigerant line 16. During operation of the system 10, when the controller 100 determines that the refrigerant charge is excessive for the current operating conditions, the controller 100 opens the refrigerant flow control device 85 to allow refrigerant vapor to flow into the receiver 60. Once the refrigerant charge has been reduced as desired, the controller 100 closes the refrigerant flow control device 85, thereby trapping high pressure refrigerant vapor within the

receiver 60. When the system 10 is in an off-cycle, the controller 100 can return refrigerant vapor to the closed-loop refrigerant circuit to increase the system refrigerant charge by simply opening the refrigerant flow control device 85 to allow high pressure refrigerant vapor to escape the receiver 60 through the refrigerant line 16 into the refrigerant line 4 of the refrigerant circuit. When the controller 100 determines the system refrigerant charge is sufficient, the controller again closes the refrigerant flow control device 85 thereby blocking refrigerant vapor from flowing into the receiver 60 when the refrigerant vapor compression system 10 returns to operation. As previously noted, the tapping location for the refrigerant line 16 could be anywhere on the high-pressure side of the refrigerant vapor compression system 10.

[0030] Referring now to FIG. 3, in the exemplary embodiment of the refrigerant vapor compression system 10 depicted therein, the receiver 60, rather being connected in refrigerant flow communication with both the high-pressure side and the low-pressure side of the refrigerant vapor compression system 10, is connected in refrigerant flow communication with the closed-loop refrigerant circuit on the low-pressure side only through a single refrigerant line 18 tapping into the refrigerant line 4 at location downstream of the evaporator expansion valve 55 and upstream of the refrigerant heat absorption heat exchanger 50. A refrigerant flow control device 95 having an open position and a closed position is interdisposed in the refrigerant line 18. The controller 100 is operatively associated with the refrigerant flow control device 95 to selectively position the refrigerant flow control device 95 in an open or a closed position.

[0031] In this embodiment, the controller 100 adjusts the amount of the refrigerant charge circulating through the closed-loop refrigerant circuit, defined by the refrigerant lines 2, 4 and 6, as necessary to maintain at desired refrigerant discharge pressure from the compression device 20 for a particular operating point, by selectively positioning the refrigerant flow control device 95 in its open position to pass liquid refrigerant either from the closed-loop refrigerant circuit into the receiver 60 or to pass liquid refrigerant from the receiver 60 back into the closed-loop refrigerant circuit and in its closed position to block refrigerant flow through the refrigerant line 18. When the controller 100 determines that the refrigerant charge is excessive for the current operating conditions, the controller 100 shuts down the refrigerant vapor compression system 10

and, during an off-cycle of the refrigerant vapor compression system 10, opens the refrigerant flow control device 95 to allow refrigerant to flow through the refrigerant line 18 into the receiver 60. Once the refrigerant charge has been reduced as desired, the controller 100 closes the refrigerant flow control device 95, thereby trapping refrigerant vapor within the receiver 60, and the refrigerant vapor compression system 10 resumes its operation. During operation of the refrigerant vapor compression system 10, the controller 100 can return refrigerant to the closed-loop refrigerant circuit to increase the system refrigerant charge by simply opening the refrigerant flow control device 95 to allow refrigerant vapor to escape the receiver 60 through the refrigerant line 18 into the refrigerant line 4 of the closed-loop refrigerant circuit. When the controller 100 determines the system refrigerant charge is sufficient, the controller again closes the refrigerant flow control device 95 thereby blocking refrigerant from flowing from the receiver 60. Again, the tapping location for the refrigerant line 18 could be anywhere on the low-pressure side of the refrigerant vapor compression system 10.

[0032] The refrigerant flow control devices 65, 75, 85 and 95 may comprise any flow control device that is selectively positionable in at least a first open position whereat refrigerant may flow through the refrigerant line in which the flow control device is disposed and a second closed position whereat refrigerant flow is blocked through the refrigerant line in which the flow control device is disposed. For example, each of the flow control devices 65, 75, 85 and 95 may comprise a two-position solenoid valve. In an embodiment, to allow for more precise control of the refrigerant amount in the refrigerant storage device 60 the flow lines 12 and/or 14 may for example be equipped with an additional orifice or a capillary tube. The orifice or capillary tube would slow down the migration process of the refrigerant in and/or out of the of the refrigerant storage device 60, thus allowing for more precise control of the amount of the refrigerant in the refrigerant storage device. The orifice can be a part of the valve construction or a stand-alone refrigerant flow control device.

[0033] The refrigerant vapor compression system 10 can also include, among other features and options, economized cycle with provisions for vapor injection into the compressor 20. The refrigerant vapor compression system 10 can also include provisions for liquid injection to provide cooling to the compression process within the compressor

20. It is to be understood that the secondary fluid moving devices 44 and 54 may also comprise pumps circulating liquids such as water or glycol solutions in heat exchange relationship with the refrigerant circulating through the closed-loop refrigerant circuit of the refrigerant vapor compression system 10.

[0034] The foregoing description is only exemplary of the teachings of the invention. Those of ordinary skill in the art will recognize that various modifications and variations may be made to the invention as specifically described herein and equivalents thereof without departing from the spirit and scope of the invention as defined by the following claims.

We Claim:

1. A refrigerant vapor compression system comprising:
a refrigerant compression device, a refrigerant heat rejection heat exchanger for passing refrigerant received from said compression device at a high pressure in heat exchange relationship with a cooling medium, and a refrigerant heat absorption heat exchanger for passing refrigerant at a low pressure in heat exchange relationship with a medium to be cooled disposed in serial refrigerant flow communication in a closed-loop refrigerant circuit;
an expansion device disposed in the closed-loop refrigerant circuit downstream of said refrigerant heat rejection heat exchanger and upstream of said refrigerant heat absorption heat exchanger;
a refrigerant storage device defining a storage volume connected by at least one refrigerant line in fluid communication with said closed-loop refrigerant circuit; and
a refrigerant flow control device interdisposed in said at least one refrigerant line, said refrigerant flow control device having an open position wherein refrigerant may flow through said at least one refrigerant line and a closed position wherein refrigeration is blocked from flowing through said at least one refrigerant line.
2. The refrigerant vapor compression system as recited in claim 1 further comprising a controller operatively associated with said refrigerant flow control device for selectively positioning said refrigerant flow control device in either an open position or in a closed position.
3. The refrigerant vapor compression system as recited in claim 1 wherein said at least one refrigerant line connecting the storage volume of said refrigerant storage device in fluid communication with said closed-loop refrigerant circuit comprises:
a single refrigerant line in fluid communication with said closed-loop refrigerant circuit at a location on a high-pressure side of the refrigerant system.

4. The refrigerant vapor compression system as recited in claim 1 wherein said at least one refrigerant line connecting the storage volume of said refrigerant storage device in fluid communication with said closed-loop refrigerant circuit comprises:

a single refrigerant line in fluid communication with said closed-loop refrigerant circuit at a location on a low-pressure side of the refrigerant system.

5. The refrigerant vapor compression system as recited in claim 1 wherein said at least one refrigerant line connecting the storage volume of said refrigerant storage device in fluid communication with said closed-loop refrigerant circuit comprises:

a first refrigerant line connecting an upper portion of the storage volume of said refrigerant storage device in fluid communication with said closed-loop refrigerant circuit at a location on a high-pressure side of the refrigerant system; and

a second refrigerant line connecting a lower portion of the storage volume of said refrigerant storage device in fluid communication with said closed-loop refrigerant circuit at a location on a low-pressure side of the refrigerant system.

6. The refrigerant vapor compression system as recited in claim 5 wherein a refrigerant flow control device interdisposed in said at least one refrigerant line comprises:

a first refrigerant flow control device interdisposed in said first refrigerant line; and

a second refrigerant flow control device interdisposed in said second refrigerant line.

7. The refrigerant vapor compression system as recited in claim 1 wherein said refrigerant vapor compression system operates in a transcritical cycle at least for a portion of the time.

8. The refrigerant vapor compression system as recited in claim 1 wherein a refrigerant circulating throughout said refrigerant vapor compression system is carbon dioxide.

9. A refrigerant vapor compression system comprising:

a refrigerant compression device having a refrigerant discharge outlet and a refrigerant suction inlet, a refrigerant heat rejection heat exchanger for passing refrigerant received from said compression device at a high pressure in heat exchange relationship with a cooling medium, and a refrigerant heat absorption heat exchanger for passing refrigerant at a low pressure in heat exchange relationship with a medium to be cooled disposed in serial refrigerant flow communication in a closed-loop refrigerant circuit;

an expansion device disposed in the closed-loop refrigerant circuit downstream of said refrigerant heat rejection heat exchanger and upstream of said refrigerant heat absorption heat exchanger; and

a refrigerant storage device defining a chamber having an upper zone and a lower zone, the upper zone connected by a first refrigerant line in fluid communication with a high-pressure side of said closed-loop refrigerant circuit at a location upstream, with respect to refrigerant flow, of said expansion device, the lower zone connected by a second refrigerant line in fluid communication with a low-pressure side of said closed-loop refrigerant circuit at a location downstream, with respect to refrigerant flow, of said expansion device.

10. The refrigerant vapor compression system as recited in claim 9 further comprising:

a first refrigerant flow control device interdisposed in said first refrigerant line;
and

a second refrigerant flow control device interdisposed in said second refrigerant line.

11. The refrigerant vapor compression system as recited in claim 10 wherein each of said first and second refrigerant flow control devices has an open position and a closed position.

12. The refrigerant vapor compression system as recited in claim 11 wherein each of said first and second refrigerant flow control devices comprises a solenoid valve having an open position and a closed position.

13. The refrigerant vapor compression system as recited in claim 10 further comprising a controller operatively associated with each of said first and second refrigerant flow control devices for selectively positioning one of said first and second refrigerant flow control devices in an open position and simultaneously selectively positioning the other of said first and second refrigerant flow control devices in a closed position.

14. The refrigerant vapor compression system as recited in claim 9 wherein said refrigerant vapor compression system operates in a transcritical cycle at least for a portion of the time.

15. The refrigerant vapor compression system as recited in claim 9 wherein a refrigerant circulating throughout said refrigerant vapor compression system is carbon dioxide.

16. A method for managing refrigerant charge in a refrigerant vapor compression system operating in a transcritical cycle at least for a portion of the time, the refrigerant vapor compression system having a refrigerant compression device, a refrigerant heat rejection heat exchanger and a refrigerant heat absorption heat exchanger disposed in serial refrigerant flow communication in a closed-loop refrigerant circuit, with an expansion device disposed in the closed-loop refrigerant circuit downstream of the refrigerant heat rejection heat exchanger and upstream of the refrigerant heat absorption heat exchanger, said method comprising the steps of:

- selectively withdrawing refrigerant from the closed-loop refrigerant circuit;
- storing the withdrawn refrigerant in a refrigerant storage device; and
- returning the withdrawn refrigerant from the refrigerant storage device to the closed-loop refrigerant circuit.

17. The method as recited in claim 16 wherein:

the step of selectively withdrawing refrigerant from the closed-loop refrigerant circuit is executed during an operating cycle of the refrigerant vapor compression system; and

the step of returning the withdrawn refrigerant from the refrigerant storage device to the closed-loop refrigerant circuit is also executed during an operating cycle of the refrigerant vapor compression system.

18. The method as recited in claim 16 wherein:

the step of selectively withdrawing refrigerant from the closed-loop refrigerant circuit is executed during an operating cycle of the refrigerant vapor compression system; and

the step of returning the withdrawn refrigerant from the refrigerant storage device to the closed-loop refrigerant circuit is executed during an off-cycle of the refrigerant vapor compression system.

19. The method as recited in claim 16 wherein:

the step of selectively withdrawing refrigerant from the closed-loop refrigerant circuit is executed during an off-cycle cycle of the refrigerant vapor compression system; and

the step of returning the withdrawn refrigerant from the refrigerant storage device to the closed-loop refrigerant circuit is executed during an operating cycle of the refrigerant vapor compression system.