

(19) World Intellectual Property Organization  
International Bureau



(43) International Publication Date  
28 February 2008 (28.02.2008)

PCT

(10) International Publication Number  
**WO 2008/024102 A1**

(51) International Patent Classification:

F25D 15/00 (2006.01) F28D 5/00 (2006.01)  
F25D 21/00 (2006.01) B01D 47/00 (2006.01)  
F25D 21/06 (2006.01) B01D 47/06 (2006.01)  
F25B 47/00 (2006.01) B01D 5/00 (2006.01)  
F25B 1/10 (2006.01)

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(21) International Application Number:

PCT/US2006/032547

(22) International Filing Date: 21 August 2006 (21.08.2006)

(25) Filing Language: English

(26) Publication Language: English

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

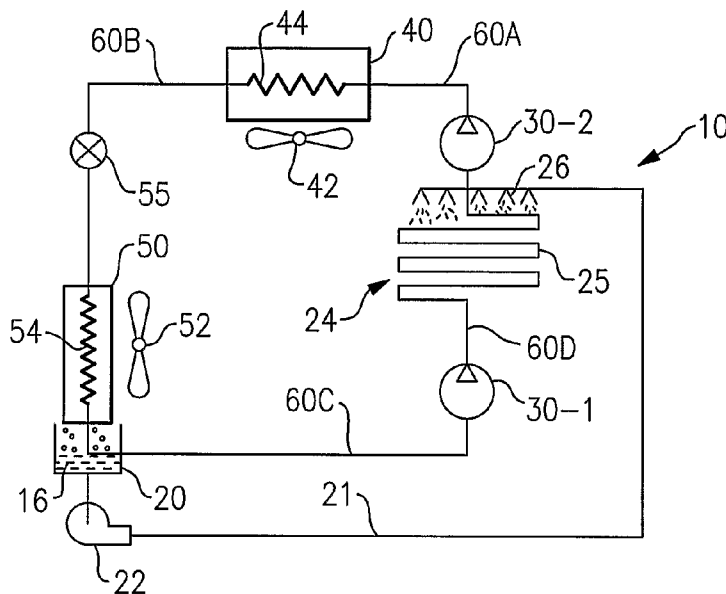
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Published:  
— with international search report

(54) Title: VAPOR COMPRESSION SYSTEM WITH CONDENSATE INTERCOOLING BETWEEN COMPRESSION STAGES



(57) Abstract: A refrigerant vapor compression system includes a first compression device and a second compression device disposed in a refrigerant circuit in series relationship with respect to refrigerant flow and an intercooler adapted to cool the refrigerant passing from the first compression device to the second compression. An evaporator is provided in the refrigerant circuit wherein the refrigerant accepts heat from a moisture bearing gas such as air. Condensate formed of moisture condensing out of the gas is collected and supplied to the intercooler for cooling the refrigerant flowing from the first compression device to the second compression device.

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## Vapor Compression System With Condensate Intercooling Between Compression Stages

### Field of the Invention

[0001] This invention relates generally to vapor compression systems having multiple compression stages and, more particularly, to the cooling of refrigerant vapor passing between an upstream compression stage and a downstream compression stage in a refrigerant vapor compression system.

### Background of the Invention

[0002] Refrigerant vapor compression systems are well known in the art and commonly used for conditioning secondary fluid such as air to be supplied to a climate controlled comfort zone within a residence, office building, hospital, school, restaurant or other facility. Refrigerant vapor compression systems are also commonly used in transport and stationary refrigeration applications for refrigerating air supplied to a temperature controlled space of a truck, trailer, container, display case or the like for preserving perishable items. Traditionally, most of these refrigerant vapor compression systems operate at subcritical refrigerant pressures and typically include a compressor, a condenser, an evaporator, and an expansion device. Commonly, an expansion device is disposed upstream, with respect to refrigerant flow, of the evaporator and downstream of the condenser. These basic refrigerant system components are interconnected by refrigerant lines in a closed refrigerant circuit, arranged in accord with known refrigerant vapor compression cycles, and operated in the subcritical pressure range for the particular refrigerant in use. Refrigerant vapor compression systems operating in the subcritical range are commonly charged with fluorocarbon refrigerants such as, but not limited to, hydrochlorofluorocarbons (HCFCs), such as R22, and more commonly hydrofluorocarbons (HFCs), such as R134a, R410A and R407C.

[0003] Although HFC refrigerants are more environmentally friendly than the chlorine containing HCFC refrigerants that they replaced, "natural" refrigerants, such as carbon dioxide, are being turned to for use in air conditioning and refrigeration systems instead of HFC refrigerants. However, because carbon dioxide has a low critical point, a vast majority of refrigerant vapor compression systems

charged with carbon dioxide as the refrigerant are designed for operation in the transcritical cycle. In refrigerant vapor compression systems operating in a transcritical cycle, the heat rejection heat exchanger operates at refrigerant pressures above the critical point, while the evaporator operates at refrigerant pressures in the subcritical range. Additionally, refrigerant vapor compression systems utilizing a low critical point refrigerant, such as carbon dioxide, frequently employ a multi-stage compression system, either multiple compressors disposed in series flow arrangement with respect to refrigerant flow or a single compressor having at least two compression stages. Typically, the pressure of the refrigerant vapor discharging from the final stage of the compression system, commonly referred to as the discharge pressure or the high-side pressure, is high enough that the refrigerant vapor does not condense as it traverses the heat rejection heat exchanger. Consequently, with respect to systems operating in a transcritical cycle, the heat rejection heat exchanger is commonly referred to as, and functions as, a gas cooler, not a condenser.

**[0004]** It is well appreciated by practitioners skilled in the art of vapor compression that it is desirable to insert an intercooler in the refrigerant circuit between compression stages in a multi-stage compression system charged with a low critical point refrigerant such as carbon dioxide. The vapor passing from the discharge of an upstream compression stage to the suction of a downstream compression stage flows in heat exchange relationship with a cooling medium as the vapor traverses the intercooler thereby cooling the vapor to improve the cycle performance and to decrease the refrigerant discharge temperature. In conventional transcritical vapor compression systems employing intercoolers, the cooling medium is generally a secondary cooling fluid external to the system, such as chilled water or ambient air, or a portion of the cold system refrigerant diverted from elsewhere within the refrigerant circuit.

**[0005]** U.S. Patent No. 6,658,888 discloses a multi-stage compression refrigerant vapor compression system charged with carbon dioxide refrigerant and having an intercooler between stages of a multi-stage compressor. The refrigerant vapor passing between compression stages traverses the intercooler wherein it rejects heat to the same cooling fluid medium having previously passed through the gas cooler accepting heat from the refrigerant vapor discharged from the

compressor. After traversing the intercooler, the heated cooling fluid medium exits the system. The cooling fluid medium may be room air, tap water or recirculated water, depending upon the application.

[0006] U.S. Patent No. 6,698,234 also discloses a multi-stage compression refrigerant vapor compression system charged with carbon dioxide refrigerant and having an intercooler between stages of a multi-stage compression system. In an embodiment disclosed therein, a portion of the cold refrigerant downstream of the gas cooler bypasses the system evaporator and is diverted to pass through the intercooler in heat exchange relationship with the refrigerant vapor flowing between compression stages. The diverted refrigerant is expanded to a lower pressure and temperature prior to passing through the intercooler. As the two refrigerant streams pass in heat exchange relationship in the intercooler, the diverted refrigerant stream is heated and the refrigerant vapor flowing between compression stages is cooled. The heated diverted refrigerant is returned to the suction side of the refrigerant circuit downstream of the system evaporator.

[0007] It has to be noted that conventional subcritical multi-stage vapor compression systems also benefit from intercoolers, although these benefits are not as pronounced as for transcritical systems.

### **Summary of the Invention**

[0008] It is an object of the invention to provide a multi-stage vapor compression system including an intercooler for cooling vapor passing between compression stages that use evaporator condensate water as the cooling medium in the intercooler.

[0009] The refrigerant vapor compression system of the invention includes a first compression device to compress a refrigerant to a first pressure, a second compression device to further compress the refrigerant from the first pressure to a second pressure, a heat accepting heat exchanger (e.g. evaporator) for passing the refrigerant in heat exchange relationship with a moisture bearing gas (e.g. air) whereby the heat is transferred from the gas to the refrigerant and at least some amount of moisture in the moisture bearing gas is condensed to form a condensate (water), and an intercooler wherein the condensate exchanges heat with and accepts

heat from the refrigerant passing from said first compression device to the second compression device.

[0010] In an embodiment, the first compression device is a first compressor and the second compression device is a second compressor with the discharge outlet of the first compressor connected by a refrigerant line in refrigerant flow communication to the suction inlet of the second compressor. The refrigerant line connecting the discharge outlet of the first compressor to the suction inlet of the second compressor traverses the intercooler. In another embodiment, the first compression device is a first compression stage of a compressor and the second compression device is a second compression stage of the same compressor. The refrigerant being compressed in the compressor traverses the intercooler as it passes from the first compression stage to the second compression stage.

[0011] In an embodiment, the intercooler includes a refrigerant conveying passage having an exterior heat exchange surface, which can be enhanced for better heat transfer by one of the techniques known in the art, and at least one spray nozzle to spray the condensate condensed from the moisture bearing gas onto the exterior heat exchange surface of the refrigerant conveying passage. Alternatively, a heat exchanger construction may be provided for the intercooler, preferably having moisture and refrigerant flows arranged in a counterflow configuration. A condensate collector may be provided in operative association with the heat accepting heat exchanger for collecting the condensate condensed from the moisture bearing gas. Condensate may be gravity-fed from the condensate collector to the spray nozzle or nozzles if the condensate collector is disposed at a higher elevation than the intercooler. Alternatively, a pump may be provided to supply the condensate from the condensate collector to the intercooler.

[0012] In another aspect of the invention, a method is provided for increasing the capacity of a refrigerant vapor compression system by cooling the refrigerant between a first compression stage and a second compression stage via heat exchange with the condensate. The method of the invention includes the steps of: compressing the refrigerant to a first pressure in a first compression stage and to a second pressure in a second compression stage, passing the refrigerant in heat exchange relationship with a moisture bearing gas whereby the refrigerant accepts heat from the gas and at least a portion of the moisture condenses from the gas to

form a condensate, and cooling the refrigerant between the first compression stage and the second compression stage via heat exchange with the condensate. The step of cooling the refrigerant passing between the first compression stage and the second compression stage via heat exchange with the condensate may comprise cooling the refrigerant between the first compression stage and the second compression stage via evaporating at least a portion of the condensate. The method may include the steps of passing the refrigerant flowing between the first compression stage and the second compression stage through a refrigerant conveying passage that may or may not have internal and external enhanced heat transfer surfaces and spraying the condensate onto the refrigerant conveying passage. Condensate delivery may be accomplished with assistance of gravity or mechanical means such as a condensate pump.

[0013] In a further aspect of the invention, a refrigerant vapor compression system includes a first compressor to compress a refrigerant to a first pressure, a second compressor to further compress the refrigerant to a second pressure, a refrigerant circuit including a first refrigerant line (or lines) passing through other refrigerant system components and connecting the discharge outlet of the second compressor in refrigerant flow communication with the suction inlet of the first compressor and a second refrigerant line connecting the discharge outlet of the first compressor with the suction inlet of the second compressor, a heat rejecting heat exchanger disposed in the first refrigerant line downstream with respect to refrigerant flow of the discharge outlet of said second compressor, a heat accepting heat exchanger disposed in the first refrigerant line downstream with respect to refrigerant flow of the heat rejecting heat exchanger for passing the refrigerant in heat exchange relationship with a moisture bearing gas whereby the refrigerant accepts heat from the gas and moisture in the gas is at least partially condensed to form a condensate, an expansion device operative to expand the refrigerant passing through the first refrigerant line from the heat rejecting heat exchanger to the heat accepting heat exchanger, and an intercooler disposed in the second refrigerant line wherein the refrigerant passing from the first compressor to the second compressor exchanges heat with the condensate whereby the refrigerant passing from the first compressor to the second compressor is cooled.

**Brief Description of the Drawings**

[0014] For a further understanding of these and other objects 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:

[0015] Figure 1 is a schematic diagram illustrating a first exemplary embodiment of a refrigerant vapor compression system in accord with the invention;

[0016] Figure 2 is a schematic diagram illustrating a second exemplary embodiment of a refrigerant vapor compression system in accord with the invention;

[0017] Figure 3 is a schematic diagram illustrating a third exemplary embodiment of a refrigerant vapor compression system in accord with the invention; and

[0018] Figure 4 is a schematic diagram illustrating a fourth exemplary embodiment of a refrigerant vapor compression system in accord with the invention.

**Detailed Description of the Invention**

[0019] Referring now to FIGS. 1-4, as in conventional systems, the refrigerant vapor compression system 10 includes a compression device 30, a refrigerant heat rejecting heat exchanger 40, also referred to herein as a gas cooler or a condenser (depending on an application), a refrigerant heat absorbing heat exchanger 50, also referred to herein as an evaporator, an expansion device 55, illustrated as an expansion valve, operatively associated with the evaporator 50, and various refrigerant lines 60A, 60B, 60C and 60D connecting the aforementioned components in a conventional refrigerant circuit. The compression device 30 functions to compress and circulate refrigerant throughout the refrigerant circuit as will be discussed in further detail hereinafter. The compression device 30 may be a scroll compressor, a screw compressor, a reciprocating compressor, a rotary compressor, a centrifugal compressor or any other type of compressor or a plurality of any such compressors. The compression device 30, as depicted in FIGS. 1-4, has a first compression stage 30-1 and a second compression stage 30-2. The compression device 30 may be a pair of compressors 30-1 and 30-2, for example a pair of scroll compressors, screw compressors, reciprocating compressors or rotary compressors connected in series, having a refrigerant line 60D connecting the discharge outlet port of the first compressor 30-1, which constitutes the first

compression stage, in refrigerant flow communication with the suction inlet port of the second compressor 30-2, which constitutes the second compression stage. Alternatively, the compression device 30 may be a single refrigerant compressor having a first compression stage and a second compression stage, for example a scroll compressor or a screw compressor having at least a pair of staged compression pockets 30-1, 30-2, or a reciprocating compressor having a first bank 30-1 and a second bank 30-2 of cylinders. Also, it has to be understood that although only two compression stages 30-1 and 30-2 are depicted in the FIGS. 1-4, any number of compression stages connected in series is within the scope of this invention and can benefit from the invention. Further, one or more compression stage may consist of two or more compressors disposed in a so-called tandem arrangement, that is compressors operating in parallel and having at least one common manifold.

[0020] The refrigerant vapor compression system of the invention may be operated in either a subcritical cycle or a transcritical cycle. In a refrigerant vapor compression system operating in a subcritical cycle, the refrigerant heat rejecting heat exchanger 40 constitutes a refrigerant condensing heat exchanger through which hot, high pressure refrigerant vapor discharged from the compression device 30-2 passes in heat exchange relationship with a secondary cooling medium, most commonly ambient air in air conditioning systems or refrigeration systems. In a refrigerant vapor compression system operating in a transcritical cycle, the refrigerant heat rejecting heat exchanger 40 constitutes a gas cooler heat exchanger through which supercritical refrigerant vapor discharged from the compression device 30-2 passes in heat exchange relationship with a secondary cooling medium, again most commonly ambient air in air conditioning systems or refrigeration systems. In either case, the refrigerant passing through the heat exchanger 40 rejects heat as it passes in heat exchange relationship with a secondary cooling fluid, typically ambient air passed over the refrigerant conveying passages 44 by an air mover, such as one or more fans 42 operatively associated with the heat exchanger 40.

[0021] Whether the system 10 is operating in a subcritical or a transcritical cycle, the refrigerant leaving the heat rejecting heat exchanger 40 passes through refrigerant line 60B to the evaporator 50. In doing so, the refrigerant traverses the expansion device 55 and expands to a lower pressure whereby the refrigerant

typically enters the evaporator 50 as a lower temperature, lower pressure mixture of liquid and vapor. The evaporator 50 constitutes a refrigerant evaporating heat exchanger through which the liquid refrigerant passes in heat exchange relationship with a heating fluid whereby the liquid refrigerant is evaporated and typically superheated. The heating fluid (or the fluid to be cooled) passed in heat exchange relationship with the refrigerant in the evaporator 50 may be air passed over the evaporator external surfaces by an air mover, such as one or more fans 52, and thereafter supplied to a climate controlled environment such as a comfort zone associated with an air conditioning system or a perishable product storage zone associated with a refrigeration unit. As the air passes over the refrigerant conveying passages 54 and other heat transfer enhancement elements (not shown) associated with the passages 54 of the evaporator 50, at least a portion of moisture contained in the air condenses out onto the exterior surfaces of the evaporator and the condensed moisture, referred to as condensate 16, then drains into a condensate collection device 20, for example a drain pan.

[0022] The lower pressure refrigerant vapor exiting the evaporator 50 returns through refrigerant line 60D to the suction port of the compression device 30-1. The expansion device 55 may be a conventional thermostatic expansion valve (TXV) or electronic expansion valve (EXV) or a fixed restriction device such as an orifice, an accumulator, a capillary tube, or the like. As in conventional refrigerant vapor compression systems, a sophisticated expansion device receives a signal indicative of the refrigerant temperature sensed by the temperature sensing element (not shown) associated with the outlet of the evaporator 50, which may be a conventional temperature sensing element, such as a bulb for a TXV and a thermistor or a thermocouple, frequently coupled with a pressure sensor, for an EXV, and meters the refrigerant flow through the refrigerant line 60C to maintain a desired level of superheat of the refrigerant vapor leaving the evaporator 50. As in conventional practice, a suction accumulator (not shown) may be disposed in refrigerant line 60C downstream with respect to refrigerant flow of the evaporator 50 and upstream with respect to refrigerant flow of the compression device 30-1 to remove and store any liquid refrigerant passing through refrigerant line 60C, thereby ensuring that liquid refrigerant does not pass to the suction port of the compression device 30-1. As

known, suction accumulators are typically used in heat pump applications and employed in conjunction with fixed restriction expansion devices.

[0023] Additionally, the refrigerant vapor compression system 10 includes an intercooler 24 disposed in the refrigerant circuit between the first compression device 30-1 and the second compression device 30-2. Refrigerant vapor passing from the evaporator 50 through refrigerant line 60C enters the suction inlet of the first compression device 30-1, wherein the refrigerant vapor is compressed to a higher intermediate pressure. The refrigerant vapor then passes from the discharge outlet of the first compression device 30-1 through refrigerant line 60D to enter the suction inlet of the second compression device 30-2 wherein the refrigerant vapor is compressed to a still higher discharge pressure before passing from the discharge outlet of the second compression device 30-2 into refrigerant line 60A. As the refrigerant vapor passes through refrigerant line 60D, the refrigerant vapor traverses the intercooler 24 wherein the refrigerant vapor passing through the intercooler 24 is cooled via rejecting heat to the evaporator condensate 16.

[0024] In the embodiment of the refrigerant vapor compression system 10 of the invention depicted in FIG. 1, a pump 22 draws condensate 16 collecting in the evaporator drain pan 20 therefrom and passes the condensate 16 through condensate line 21 to a bank of spray nozzles 26. The spray nozzles 26 are arrayed in operative association with a refrigerant conveying tube coil or passage 25 forming the intercooler 24 to spray condensate 16 received through condensate line 16 onto the exterior surfaces of the tubes of the coil 25. As known in the art, the exterior surfaces of the tube coil or passage 25 can be extended and enhanced for better heat transfer. The refrigerant vapor traversing through the coil 25 as it passes through refrigerant line 60D from the first compression device 30-1 to the second compression device 30-2 is cooled as it rejects heat to heat and evaporate at least a portion of the condensate 16 sprayed onto the exterior of the coil 25. To improve the evaporate cooling effect, the spray nozzles may comprise atomizers, such as atomizing nozzles or rotary atomizers, which produce a mist of relatively small size droplets of condensate onto the exterior of the coil 25.

[0025] In the embodiment of the refrigerant vapor compression system 10 of the invention depicted in FIG. 2, the pump 22 withdraws condensate 16 collecting in the evaporator drain pan 20 and passes the condensate 16 through condensate line 21

to and through the intercooler 24 in heat exchange relationship with the refrigerant passing through the intercooler 24. As the refrigerant vapor traverses the intercooler 24, the refrigerant vapor is cooled as it rejects heat to the condensate 16. The intercooler 24 may comprise a plate-type heat exchanger, a tube-in-tube heat exchanger, an immersed coil heat exchanger or any other type of heat exchanger wherein the refrigerant vapor is passed in isolation from but in heat exchange relationship with the evaporator condensate. As the condensate passes in heat exchange relationship with the refrigerant vapor, the condensate 16 is heated and/or evaporated. As noted before, as known in the art, the exterior and interior surfaces of the intercooler 24 can be enhanced to provide better heat transfer characteristics. It has to be also noted that, in this case, the intercooler coil 25 can be integrated into the construction of the drain pan 20, if desired.

[0026] In the embodiment of the refrigerant vapor compression system 10 of the invention depicted in FIG. 3, the system is simplified by removing the pump 22 and disposing the evaporator 50 and its associated condensate drain pan 20 at a higher elevation than the intercooler 24. Condensate 16 collecting in the evaporator drain pan 20 drains therefrom under the force of gravity through condensate line 21 to a plurality of spray nozzles 26. As in the embodiment in FIG. 1, the spray nozzles 26 are again arrayed in operative association with a refrigerant conveying tube coil or passage 25 forming the intercooler 24 to spray condensate 16 received through condensate line 21 onto the exterior surface of the tubes of the coil 25. The refrigerant vapor traversing through the coil 25 as it passes through refrigerant line 60D from the first compression device 30-1 to the second compression device 30-2 is cooled as it rejects heat to heat and at least partially evaporate the condensate 16 sprayed onto the exterior of the coil 25. To improve the evaporate cooling effect, the spray nozzles may comprise atomizers, such as atomizing nozzles or rotary atomizers, which produce a mist of relatively small size droplets of condensate onto the exterior of the coil 25.

[0027] In the embodiment of the refrigerant vapor compression system 10 of the invention depicted in FIG. 4, the intercooler 24 is a refrigerant conveying tube coil or passage 25 immersed in the condensate 16 collecting in the condensate pan 20. As noted before, the exterior surfaces of tube coils or passages 25 forming the intercooler 24 can be extended and enhanced for better heat transfer. The refrigerant

vapor flowing through the intercooler 24 as it passes through refrigerant line 60D from the first compression device 30-1 to the second compression device 30-2 is cooled as it rejects heat to heat and evaporate at least a portion of the condensate 16 collected in the condensate pan 20. In this embodiment, the evaporated condensate must be vented to the ambient environment to ensure that the evaporated condensate does not re-enter the conditioned air stream leaving the evaporator 50.

[0028] While the present invention has been particularly shown and described with reference to the preferred mode as illustrated in the drawings, it will be understood by one skilled in the art that various changes in detail may be effected therein without departing from the spirit and scope of the invention as defined by the claims. For example, those skilled in the art will recognize that many variations may be made to the exemplary embodiments described herein while still using the cooling capacity of the evaporator condensate to cool the refrigerant vapor passing between serially arranged compressors or compressor stages thereby utilizing cooling capacity that would otherwise be wasted.

**We Claim:**

1. A refrigerant vapor compression system comprising:  
at least one compression device having a first compression stage to compress a refrigerant to a first pressure and a second compression stage to further compress the refrigerant from the first pressure to a second pressure;  
a heat accepting heat exchanger for passing the refrigerant in heat exchange relationship with a moisture bearing gas whereby the heat is transferred to the refrigerant to cool moisture bearing gas and moisture in the moisture bearing gas is at least partially condensed to form a condensate; and  
an intercooler wherein the condensate exchanges heat with and accepts heat from the refrigerant passing from the first compression stage to the second compression stage.
2. A refrigerant vapor compression system as recited in claim 1 wherein the first compression stage comprises a first compressor and the second compression stage comprises a second compressor, the first compressor having a discharge outlet connected by a refrigerant line in refrigerant flow communication to a suction inlet of the second compressor.
3. A refrigerant vapor compression system as recited in claim 2 wherein the refrigerant line connecting the discharge outlet of the first compressor to the suction inlet of the second compressor traverses the intercooler.
4. A refrigerant vapor compression system as recited in claim 1 wherein the first compression stage comprises a first compression stage of a compressor and the second compression stage comprises a second compression stage of the same compressor, the refrigerant being compressed in the compressor passes from the first compression stage to the second compression stage.
5. A refrigerant vapor compression system as recited in claim 4 wherein the refrigerant passing from the first compression stage to the second compression stage traverses the intercooler.

6. A refrigerant vapor compression system as recited in claim 1 further comprising a condensate collector operatively associated with the heat accepting heat exchanger for collecting the condensate condensed from the moisture bearing gas.
7. A refrigerant vapor compression system as recited in claim 6 further comprising a pump to supply the condensate from the condensate collector to the intercooler.
8. A refrigerant vapor compression system as recited in claim 1 wherein said intercooler comprises:  
refrigerant conveying passages having an exterior heat exchange surface; and  
at least one spray nozzle to spray the condensate condensed from the moisture bearing gas onto the exterior heat exchange surface of the refrigerant conveying passages.
9. A refrigerant vapor compression system as recited in claim 8 wherein the at least one spray nozzle comprises an atomizing nozzle.
10. A refrigerant vapor compression system as recited in claim 8 wherein the at least one spray nozzle comprises a rotary atomizer.
11. A refrigerant vapor compression system as recited in claim 8 further comprising a condensate collector operatively associated with the heat accepting heat exchanger for collecting the condensate condensed from the moisture bearing gas.
12. A refrigerant vapor compression system as recited in claim 11 further comprising a pump to supply the condensate from the condensate collector to the at least one spray nozzle.
13. A refrigerant vapor compression system as recited in claim 1 wherein the refrigerant is carbon dioxide.

14. A refrigerant vapor compression system as recited in claim 1 wherein said intercooler comprises a heat exchange device incorporating refrigerant conveying passages having an exterior heat exchange surface in contact with the condensate.
15. A refrigerant vapor compression system as recited in claim 14 wherein the intercooler heat exchange device is selected from the group consisting of a plate heat exchanger, tubular heat exchanger and immersed coil heat exchanger.
16. A refrigerant vapor compression system as recited in claim 14 further comprising a condensate collector operatively associated with the heat accepting heat exchanger for collecting the condensate condensed from the moisture bearing gas.
17. A refrigerant vapor compression system as recited in claim 16 further comprising a pump to supply the condensate from the condensate collector to the intercooler.
18. A refrigerant vapor compression system as recited in claim 1 wherein the intercooler comprises a condensate collector operatively associated with the heat accepting heat exchanger for collecting the condensate condensed from the moisture bearing gas and the intercooler heat exchange device is a refrigerant conveying passage immersed in the condensate in said condensate collector.
19. A refrigerant vapor compression system as recited in claim 1, wherein at least one of said first and second compression stages comprises at least a pair of compressors disposed in a tandem compressor configuration.
20. A method of improving performance of a refrigerant vapor compression system comprising the steps of:
  - compressing the refrigerant to a first pressure in a first compression stage and to a second pressure in a second compression stage;

passing the refrigerant in heat exchange relationship with a moisture bearing gas whereby the refrigerant accepts heat from the gas cooling the gas and at least a portion of the moisture condenses from the gas to form a condensate; and

cooling the refrigerant between the first compression stage and the second compression stage via heat exchange with the condensate.

21. A method as recited in claim 20 wherein the step of compressing the refrigerant to a first pressure in a first compression stage and to a second pressure in a second compression stage comprises compressing the refrigerant to a first pressure in a first compressor and compressing the refrigerant to a second pressure in a second compressor, the second compressor receiving refrigerant from the first compressor substantially at the first pressure.

22. A method as recited in claim 20 wherein the step of compressing the refrigerant to a first pressure in a first compression stage and to a second pressure in a second compression stage comprises compressing the refrigerant to a first pressure in a first stage of a compressor and compressing the refrigerant to a second pressure in a second stage of the same compressor.

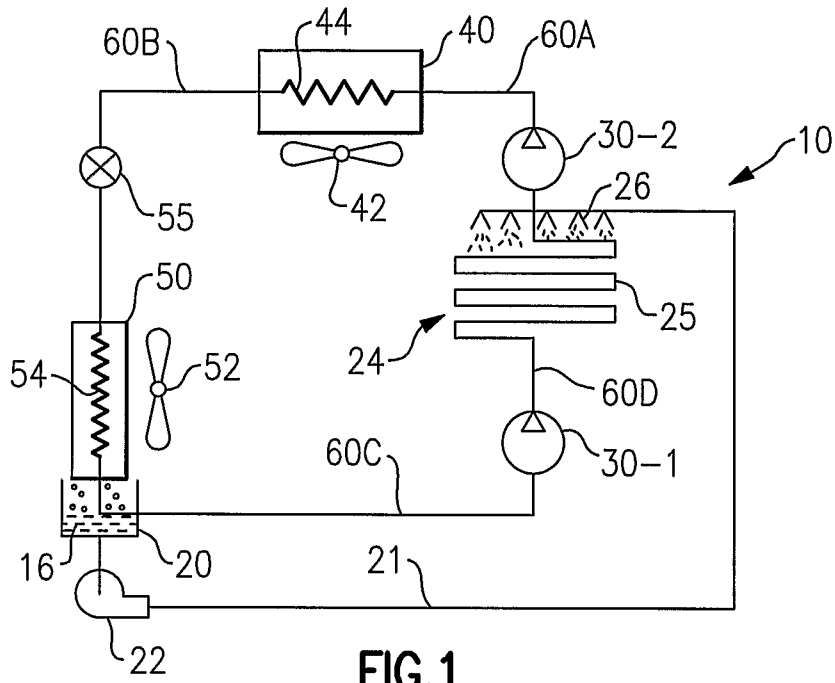
23. A method as recited in claim 20 wherein the step of cooling the refrigerant passing between the first compression stage and the second compression stage via heat exchange with the condensate includes evaporating at least a portion of the condensate.

24. A method as recited in claim 23 further comprising the steps of:  
passing the refrigerant flowing between the first compression stage and the second compression stage through at least one refrigerant conveying passage; and  
spraying the condensate onto the at least one refrigerant conveying passage.

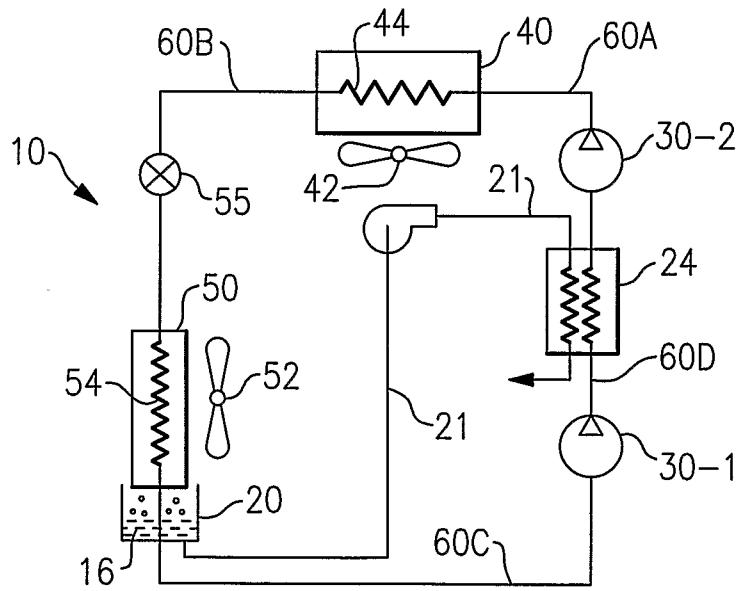
25. A method as recited in claim 23 further comprising the step of:  
passing the refrigerant flowing between the first compression stage and the second compression stage through at least one refrigerant conveying passage immersed in the condensate.

26. A method as recited in claim 20 wherein the refrigerant is carbon dioxide.
27. A refrigerant vapor compression system comprising:
- a first compressor to compress a refrigerant to a first pressure, said first compressor having a suction inlet and a discharge outlet;
  - a second compressor to further compress the refrigerant to a second pressure, the second compressor having a suction inlet and a discharge outlet;
  - a refrigerant circuit including a first refrigerant line connecting the discharge outlet of said second compressor in refrigerant flow communication with the suction inlet of said first compressor and a second refrigerant line connecting the discharge outlet of said first compressor with the suction inlet of said second compressor;
  - a heat rejecting heat exchanger for passing refrigerant in heat exchange relationship with a cooling fluid whereby the refrigerant rejects heat to the cooling fluid, said heat rejecting heat exchanger disposed in the first refrigerant line downstream with respect to refrigerant flow of the discharge outlet of said second compressor;
  - a heat accepting heat exchanger for passing the refrigerant in heat exchange relationship with a moisture bearing gas whereby the refrigerant accepts heat from the gas to cool the gas and moisture in the gas is at least partially condensed to form a condensate, said heat accepting heat exchanger disposed in the first refrigerant line downstream with respect to refrigerant flow of said heat rejecting heat exchanger;
  - an expansion device disposed in the refrigerant circuit downstream with respect to refrigerant flow of said heat rejecting heat exchanger and upstream with respect to refrigerant flow of said heat accepting heat exchanger, said expansion device operative to expand to lower pressure and temperature the refrigerant passing through the first refrigerant line from said heat rejecting heat exchanger to said heat accepting heat exchanger; and
  - an intercooler disposed in the second refrigerant line wherein the refrigerant passing from said first compressor to second compressor exchanges heat with the condensate whereby the refrigerant passing from said first compressor to said second compressor is cooled by the condensate.

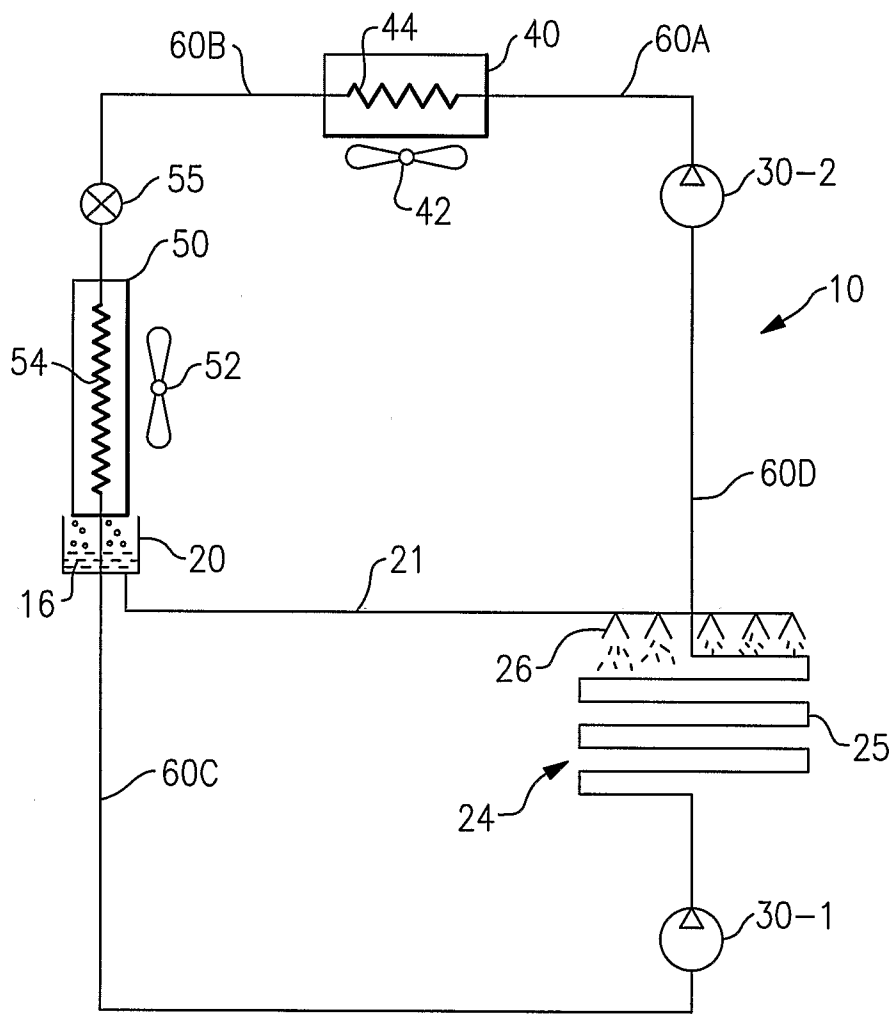
28. A refrigerant vapor compression system as recited in claim 27 wherein the refrigerant is carbon dioxide.
29. A refrigerant vapor compression system as recited in claim 27 wherein said intercooler comprises a heat exchange device incorporating refrigerant conveying passages having an exterior heat exchange surface in contact with the condensate.
30. A refrigerant vapor compression system as recited in claim 29 wherein the intercooler heat exchange device is selected from the group consisting of a plate heat exchanger, tubular heat exchanger and immersed coil heat exchanger.
31. A refrigerant vapor compression system as recited in claim 27 further comprising a condensate collector operatively associated with the heat accepting heat exchanger for collecting the condensate condensed from the moisture bearing gas.
32. A refrigerant vapor compression system as recited in claim 27 further comprising a pump to supply the condensate from the condensate collector to the intercooler.
33. A refrigerant vapor compression system as recited in claim 27 wherein the intercooler comprises a condensate collector operatively associated with the heat accepting heat exchanger for collecting the condensate condensed from the moisture bearing gas and the intercooler heat exchange device is a refrigerant conveying passage immersed in the condensate in said condensate collector.



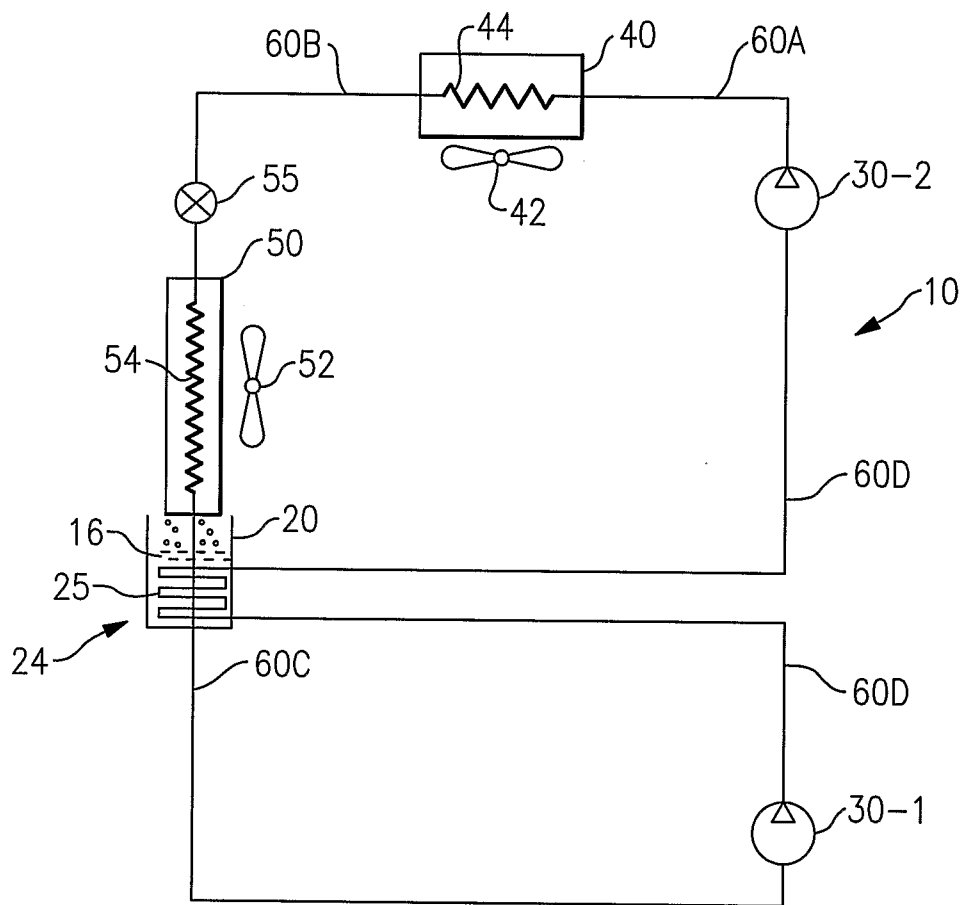
**FIG. 1**



**FIG. 2**



**FIG.3**



**FIG.4**

**INTERNATIONAL SEARCH REPORT**

International application No.

PCT/US06/32547

**A. CLASSIFICATION OF SUBJECT MATTER**  
**IPC:** F25D 15/00( 2006.01),21/00( 2006.01),21/06( 2006.01);F25B 47/00( 2006.01),1/10( 2006.01);F28D 5/00( 2006.01);B01D 47/00( 2006.01),47/06( 2006.01),5/00( 2006.01)  
  
**USPC:** 62/119,272,279,280,291,304,305,510;261/34.1,78.1,111,158;165/60  
 According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)  
 U.S. : 62/119,272,279,280,291,304,305,510;261/34.1,78.1,111,158;165/60

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)  
 Conducted electronic search by using search engine EAST.

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4,406,138 A (NELSON) 27 September 1983, see the entire document.	1-33
A	US 6,715,312 B1 (TEAKELL) 6 April 2004, see the entire document.	1-33
A	US 6,318,108 B1 (HOLSTEIN et al) 20 November 2001, see the entire document.	1-33
A	US 6,817,206 B2 (SHAHBAZ) 16 November 2004.	1-33

Further documents are listed in the continuation of Box C.

See patent family annex.

* Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier application or patent published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means		
"P" document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search  
 06 December 2006 (06.12.2006)

Date of mailing of the international search report

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