REFRIGERANT SYSTEM AND METHOD OF OPERATING THE SAME

Inventors: Michael F. Taras, Fayetteville, NY (US); Alexander Lifson, Manlius, NY (US)
Assignee: CARRIER CORPORATION, Farmington, CT (US)

Publication Classification

Int. Cl.
F25B 1/00 (2006.01)
F25B 1/06 (2006.01)
F25B 41/00 (2006.01)
F25B 41/04 (2006.01)
U.S. Cl. 62/115; 62/500; 62/513; 62/196.1

ABSTRACT

The present disclosure provides a refrigerant system that comprises a compressor, a main refrigerant circuit, an economizer refrigerant circuit, and a bypass refrigerant circuit. The refrigerant system further comprises a single refrigerant flow control device switching between different operational modes to provide various degrees of system unloading in operation. The present disclosure also provides a method of operating the refrigerant system.
REFRIGERANT SYSTEM AND METHOD OF OPERATING THE SAME

BACKGROUND OF THE DISCLOSURE

[0001] 1. Field of the Disclosure
[0002] This disclosure relates to refrigerant systems. More particularly, this disclosure relates to refrigerant systems having economizer circuits and methods of operating such refrigerant systems.

[0003] 2. Discussion of the Related Art
[0004] Refrigerant systems are utilized to control the temperature and humidity of air in various environments to be conditioned. Typically, refrigerant systems include a refrigerant that is compressed in a compressor and delivered to a heat rejection heat exchanger. Although, as known, the heat rejection heat exchanger is a condenser for subcritical applications and a gas cooler for transcritical applications, for simplicity, it will be referred to as a condenser throughout the disclosure. In the condenser, heat is exchanged between outside ambient air (or other cooling media) and the refrigerant. From the condenser, the refrigerant passes to an expansion device, in which the refrigerant is expanded to a lower pressure and temperature, and is then passed through an evaporator. In the evaporator, heat is exchanged between the refrigerant and the indoor air, which is delivered into the environment to be conditioned. When the refrigerant system is in operation, the evaporator cools the air that is being supplied to the conditioned environment. In addition, as the temperature of the air is lowered, usually moisture is also taken out of the air. In this manner, the humidity level of the air can also be controlled.

[0005] Enhancement of system efficiency is one of the foremost concerns in the air conditioning and refrigeration industry. One of the options available to the refrigerant system designer to increase system efficiency is a so-called economizer cycle. When the economizer circuit is activated, at least a portion of the refrigerant flowing from the condenser is tapped and passed through an economizer expansion device and then to an economizer heat exchanger. This tapped refrigerant cools a main refrigerant flow that also passes through the economizer heat exchanger. The tapped refrigerant leaves the economizer heat exchanger usually in a vapor state and is injected back into the compressor at an intermediate compression point. The main refrigerant is additionally cooled after passing through the economizer heat exchanger and then flown through a main expansion device and to the evaporator. This main refrigerant flow will provide a higher capacity and/or efficiency, due to extra cooling obtained in the economizer heat exchanger. An economizer circuit thus provides enhanced system performance characteristics. As also known, there are several economizer circuit configurations that provide similar enhanced system operational functionality. For instance, the economizer flow can be tapped from the main refrigerant flow downstream (instead of upstream) of the economizer heat exchanger. Also, a flash tank, essentially representing a 100% effective economizer heat exchanger, may be utilized instead to provide similar functionality.

[0006] As known, to increase part-load efficiency, many refrigerant systems may be equipped with the unloading features. In particular, one of such unloading options available for economized refrigerant systems is a bypass unloading, when at least a portion of partially compressed refrigerant is bypassed from an intermediate compression point to the compressor suction. It has been determined by the present disclosure that many current economized refrigerant systems, and especially the systems incorporating unloading functionality, require extra refrigerant cycle and control hardware, which add to the cost and complexity of the refrigerant systems utilizing such circuits. In addition, it has been determined by the present disclosure that the cost and complexity of prior art economized refrigerant systems make it difficult and expensive to retrofit existing refrigerant systems with economizer circuits.

[0007] Accordingly, there is a need for refrigerant systems and methods of operating such systems that will mitigate these and other disadvantages of currently available economized refrigerant systems.

SUMMARY OF THE DISCLOSURE

[0008] The present disclosure provides a refrigerant system. The refrigerant system comprises a compressor having a suction port and an intermediate port, a main refrigerant circuit, an economizer refrigerant circuit, a bypass refrigerant circuit, and a refrigerant flow control device. The refrigerant flow control device has at least two positions, with a first position providing fluid communication between the economizer refrigerant circuit and at least one of the suction compressor port and the intermediate compressor port, during an economized mode of operation. A second position provides fluid communication between the intermediate port and the suction port through the bypass refrigerant circuit, during a bypass mode of operation. Additionally, the refrigerant flow control device may have a third position, at least partially isolating the economizer refrigerant circuit and the bypass refrigerant circuit from the main refrigerant circuit, during a normal mode of operation. The compressor may be a single compression device, or a pair of compressors connected in sequence, so that the discharge port of the first compression stage is connected to a suction port of the second compression stage. In the latter case, the intermediate compressor port is a point on the refrigerant line connecting the two compression stages.

[0009] The present disclosure also provides a method for operating a refrigerant system. The method comprises: selectively controlling a single refrigerant flow control device to provide the refrigerant flow through the economizer circuit, during an economized mode of operation of the refrigerant system, and to provide the refrigerant flow through the bypass circuit, during a bypass mode of operation of the refrigerant system. The method may include an additional step of controlling the same refrigerant flow control device to provide the refrigerant flow through the main refrigeration circuit, and not through the economizer refrigerant circuit or bypass refrigerant circuit, during a normal mode of operation of the refrigerant system.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. 1 shows a schematic drawing of a refrigerant system according to the present disclosure; and

[0011] FIG. 2 shows a schematic drawing of a second embodiment of a refrigerant system according to the present disclosure.

DETAILED DESCRIPTION OF THE INVENTION

[0012] Referring to FIG. 1, a refrigerant system 10 according to the present disclosure is shown. Refrigerant system 10 has a refrigerant flow control device 12 which is in commu-
nication with a controller 14. Controller 14 may be a main controller for refrigerant system 10, or a separate auxiliary controller. In one embodiment, flow control device 12 is a three-way valve and is controlled by controller 14 to selectively place a main refrigeration circuit 16 in fluid communication with an economizer refrigerant circuit 18 or a bypass refrigerant circuit 20. Flow control device 12 may have an additional position to isolate main refrigerant circuit 16 from economizer refrigerant circuit 18 and bypass refrigerant circuit 20 during a normal mode of operation of the refrigerant system 10.

Refrigerant flow control device 12 may regulate the flow of a refrigerant (not shown) through economizer refrigerant circuit 18 and/or bypass refrigerant circuit 20, with either modulated or pulsed methods of control. Flow control device 12 may also mix refrigerant flows from the economizer refrigerant circuit 18 and the bypass refrigerant circuit 20 in various proportions in a single refrigerant stream.

Therefore, refrigerant system 10 advantageously has a single refrigerant flow control device 12 to provide at least two modes of operation for the refrigeration system 10: an economized mode of operation and an unloaded mode of operation, unlike currently available refrigeration systems that require at least two refrigerant flow control devices. As such, refrigerant flow control device 12 only occupies a single output (not shown) of controller 14, unlike the two or more outputs required by conventional refrigeration systems having more than one refrigerant flow control device. Thus, the refrigerant system 10 of the present disclosure is less complex and less expensive to implement. Moreover, the present disclosure, due to the use of a single refrigerant flow control device 12, allows existing refrigeration systems to be more easily retrofitted with economizer refrigerant circuit 18 and bypass refrigerant circuit 20 than currently available equipment.

Main refrigeration circuit 16 includes a compressor 22, a condenser 24, a main expansion device 26, and an evaporator 28 in serial fluid communication with one another. In a normal mode of operation of refrigeration system 10, controller 14 controls flow control device 12 to a first position (not shown) such that refrigerant from main refrigeration circuit 16 is isolated from both economizer refrigerant circuit 18 and bypass refrigerant circuit 20. Here, and as is well known to a person of ordinary skill in the art, compressor 22 drives refrigerant through discharge refrigerant line 30 to condenser 24, from condenser 24 through liquid refrigerant line 32 to main expansion device 26, from main expansion device 26 to evaporator 28, and from evaporator 28 through suction refrigerant line 36 and back to compressor 22. Condenser 24 is an heat exchange relationship with outside air 38, while evaporator 28 is in a heat exchange relationship with a fluid to be conditioned 40, such as air delivered to a climate-controlled space. It should be noted that instead of outside air 38, other cooling media (such as, for example, circulating water or a glycol solution) can be used to cool the refrigerant in condenser 24.

For refrigerant system 10, the normal mode of operation may be optional, in addition to an economized and bypass modes of operation described below. Therefore, refrigerant flow control device 12 may have an optional position to provide a refrigerant flow through main refrigeration circuit 16, and to isolate this main refrigerant circuit 16 from economizer refrigerant circuit 18 and bypass refrigerant circuit 20, during a normal mode of operation of the refrigerant system 10.
nique, the refrigerant flow control device 12 provides variable size restrictions to the two refrigerant flows, thus simultaneously changing the hydraulic resistances and controlling the amount of refrigerant delivered into the suction and intermediate ports. In the pulse width modulation control, refrigerant flow control device 12 is rapidly switched from one economized mode of operation to the other.

[0021] Flow control device 12 can also be controlled to a third position by controller 14, placing refrigerant system 10 in a bypass unloaded mode of operation. In this mode of operation, refrigerant flows out of intermediate port 56 of compressor 22 and into bypass refrigerant circuit 20, i.e. through intermediate pressure refrigerant line 58 and bypass refrigerant line 52, before merging with the refrigerant in suction refrigerant line 36 and traveling back into suction port 54 of compressor 22. In bypass unloaded mode of operation, bypass refrigerant circuit 20 is isolated from economizer refrigerant circuit 18 but is in fluid communication with main refrigerant circuit 16. Similarly to the above description, refrigerant flow control device 12 can be controlled to regulate refrigerant flow by modulation or pulsation means.

[0022] Refrigerant flow control device 12 can also have a fourth position, during an economized/bypass mode, which puts the economizer and bypass circuits in fluid communication with each other. The economized refrigerant flow from economizer refrigerant line 58 is combined with the bypass refrigerant flow from intermediate pressure refrigerant line 58 to be routed to bypass refrigerant line 52. Various flow combinations can be provided by precise positioning of refrigerant flow control device 12, as will be discussed in further detail below.

[0023] Refrigerant line 58 can comprise two separate refrigerant lines, and intermediate port 56 of compressor 22 can comprise two separate intermediate ports, so that one of them is used during economized mode of operation, and the other is used during bypass unloaded mode of operation. Further, compressor 22 may be a single compressor unit comprising two sequential compression stages or two compressors connected in sequence with an intermediate port located in between the two compressors.

[0024] Refrigerant flow control device 12 can be, for instance, of piston or rotary type, where controlling an alignment of valve openings with corresponding refrigerant lines provides a desired mode of operation for refrigerant system 10.

[0025] The mode of operation most desirable for refrigerant system 10 can depend on the required load on compressor 22, which will be a function of the ambient temperature and the desired amount of cooling/dehumidification in the climate-controlled space to be conditioned. Based on these parameters, controller 14 can selectively position or adjust refrigerant flow control device 12 accordingly to match the thermal load demands in the conditioned space. For example, at moderate levels of thermal demands, controller 14 can position refrigerant flow control device 12 in the first position as described above, placing refrigerant system 10 in a normal cooling mode of operation. At high levels of thermal demand in the conditioned space and/or at high ambient temperatures, controller 14 can position refrigerant flow control device 12 into the second position described above, placing refrigerant system 10 in an economized mode of operation. At low ambient temperatures and/or when there is a low demand for cooling, refrigerant flow control device 12 can be placed into the third position, operating refrigerant system 10 in a bypass mode. The bypass mode can be advantageous in that at least a portion of the refrigerant in compressor 22 is not compressed fully, thus reducing the amount of work performed by the compressor and improving operational efficiency of refrigerant system 10.

[0026] As shown in Table 1 below, various combinations of operational modes described above provide intermediate levels of loading and unloading for compressor 22 that allow for refrigerant system 10 to precisely match thermal load demands in the climate-controlled space. As stated here above, refrigerant flow control device 12 and controller 14 should be capable to provide this functionality. Thus, the present disclosure has advantageously disclosed a single refrigerant flow control device 12 providing various combinations of operational modes for refrigerant system 10 at reduced complexity, cost, maintenance and improved reliability.

[0027] As shown in Table 1, refrigerant system 10 may have at least nine different configurations. For example, in configuration #1, refrigerant system 10 is capable of operating in all of the four modes described above. In configuration #2, refrigerant system 10 can operate in normal, bypass, and economizer modes only, and so on. Thus, refrigerant system 10 can be customized to the particular needs of a customer and application requirements.

<table>
<thead>
<tr>
<th>Mode</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Bypass</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Economizer</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Economizer w/ Bypass</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

[0028] It should be noted that refrigerant flow control devices referred to herein as closed include refrigerant flow control devices such as valves which are substantially closed so as to prevent meaningful flow therethrough, such that the circuits containing the valves are substantially inactive, and refrigerant flow control devices referred to as open include those which are substantially open so as to allow meaningful flow therethrough, such that the circuits containing these refrigerant flow control devices are substantially active.

[0029] It should be recognized that refrigerant system 10 is shown in FIG. 1, by way of example only, as having tap refrigerant line 46 of economizer circuit 18 selectively tapping at least a portion of refrigerant from liquid refrigerant line 32 of main refrigeration circuit 16 upstream of the frist refrigerant pass through economizer heat exchanger 44. Of course, it is contemplated by the present disclosure for economizer circuit 18 to be located anywhere in main refrigeration circuit 16 as long as economizer heat exchanger 44 is positioned upstream of main expansion device 26 and downstream of condenser 24. For example, and referring to FIG. 2, refrigerant system 10 is shown including tap refrigerant line 46 of economizer circuit 18 selectively tapping at least a portion of refrigerant from liquid refrigerant line 32 of main refrigeration circuit 16 downstream of the first pass through economizer heat exchanger 44. As was mentioned above, an economizer cycle with a flash tank may be equally utilized as well.

[0030] It should be pointed out that many different compressor types could be used in this invention. For example, scroll, screw, rotary, or reciprocating compressors can be employed. The refrigerant systems that utilize this invention
can be used in many different applications, including, but not limited to, air conditioning systems, heat pump systems, marine container units, refrigeration truck-trailer units, and supermarket refrigeration systems.

While the present disclosure has been described with reference to one or more exemplary embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the present disclosure. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the disclosure without departing from the scope thereof. Therefore, it is intended that the present disclosure not be limited to the particular embodiment(s) disclosed as the best mode contemplated, but that the disclosure will include all embodiments falling within the scope of the appended claims.

What is claimed is:
1. A refrigerant system comprising:
   a compressor having a suction port and an intermediate port;
   a main refrigerant circuit;
   an economizer refrigerant circuit;
   a bypass refrigerant circuit; and
   a flow control device, wherein said flow control device comprises:
   a first position putting said economizer refrigerant circuit in fluid communication with at least one of said suction port and said intermediate port of said compressor, during an economized mode of operation, and
   a second position putting said intermediate port of said compressor and said suction port of said compressor in fluid communication through said bypass refrigerant circuit, during a bypass mode of operation.
2. The refrigerant system of claim 1, wherein said flow control device further has a third position isolating said economizer refrigerant circuit and said bypass refrigerant circuit from said main refrigerant circuit, during a normal mode of operation.
3. The refrigerant system of claim 1, further comprising a first controller in communication with said flow control device.
4. The refrigerant system of claim 3, wherein said first controller controls the refrigerant system.
5. The refrigerant system of claim 3, wherein said first controller is in communication with a second controller, wherein said second controller controls the refrigerant system.
6. The refrigerant system of claim 1, further comprising an economizer heat exchanger in fluid communication with said compressor, wherein at least a portion of a refrigerant flowing through said main refrigerant circuit is diverted through said economizer refrigerant circuit at a point upstream of said economizer heat exchanger, during said economized mode of operation.
7. The refrigerant system of claim 1, further comprising an economizer heat exchanger in fluid communication with said compressor, wherein at least a portion of a refrigerant flowing through said main refrigerant circuit is diverted through said economizer circuit at a point downstream of said economizer heat exchanger, during said economized mode of operation.
8. The refrigerant system of claim 1, wherein said flow control device further has a third position placing said economizer refrigerant circuit and said bypass refrigerant circuit in fluid communication with each other, and with said main refrigerant circuit, during an economized bypass mode of operation.
9. The refrigerant system of claim 1, wherein said flow control device adjusts proportions of a refrigerant flowing into said suction port and said intermediate port.
10. The refrigerant system of claim 1, wherein when said flow control device is in said first position, said economizer refrigerant circuit is in fluid communication with only one of said suction port and said intermediate port.
11. The refrigerant system of claim 1, wherein said refrigerant flow control device adjusts refrigerant flow through either modulated or pulsed control.
12. The refrigerant system of claim 1, wherein said flow control device further has a third position, putting said economizer refrigerant circuit and said bypass refrigerant circuit in fluid communication.
13. The refrigerant system of claim 12, wherein said flow control device adjusts proportions of a refrigerant flowing through said economizer refrigerant circuit and said bypass refrigerant circuit.
14. The refrigerant system of claim 1, wherein said flow control device is a rotary type flow control device, or a piston type flow control device.
15. The refrigerant system of claim 1, wherein said intermediate port is a single port for accepting economized refrigerant flow from said economizer refrigerant circuit, and for discharging bypass refrigerant flow into said bypass refrigerant circuit.
16. The refrigerant system of claim 1, wherein said intermediate port of said compressor comprises a first port and a second port, wherein said first port accepts economized refrigerant flow from said economizer refrigerant circuit, and said second port discharges bypass refrigerant flow into said bypass refrigerant circuit.
17. The refrigerant system of claim 1, wherein said flow control device is a three-way valve.
18. A method of operating a refrigerant system, comprising the steps of:
   controlling a refrigerant to flow through a main refrigerant circuit and an economizer refrigerant circuit, but not a bypass refrigerant circuit, during an economizer mode of operation; and
   controlling said refrigerant to flow through said main refrigerant circuit and said bypass refrigerant circuit, but not said economizer refrigerant circuit, during a bypass mode of operation.
19. The method of claim 18, further comprising:
   controlling said refrigerant to flow through said main refrigerant circuit but not said economizer refrigerant circuit and not said bypass refrigerant circuit during a normal mode of operation.
20. The method of claim 18, further comprising:
   controlling said refrigerant to flow through said main refrigerant circuit, said economizer refrigerant circuit, and said bypass refrigerant circuit during an economized bypass mode of operation.

* * * * *