A system and method are disclosed that provide an accumulator for helping to relieve pressure during pressure spikes in an HVAC system. The accumulator can also be heated by various means, such as components of the condenser or evaporator, helping to achieve proper performance of the system. The accumulator can also serve as a receptacle for refrigerant when the system is powered down.
COMPENSATOR VALVE OPENED 302
REFRIGERANT ENTERS LIQUID LINE 304
HIGH PRESSURE IN LIQUID LINE CAUSES REFRIGERANT TO MIGRATE TO COMPENSATOR RESERVOIR 306
LOWER PRESSURE IN LIQUID LINE CAUSES REFRIGERANT TO LEAVE COMPENSATOR RESERVOIR 308

FIG. 3
FIG. 12

1800 PROVIDE AN ACCUMULATOR IN AN HVAC SYSTEM
1810 MAINTAIN ACCUMULATOR AT 5% TO 20% ABOVE THE LIQUID SATURATED TEMPERATURE DURING OPERATION
1820 DURING PRESSURE SPIKES REFRIGERANT FLOWS TO THE ACCUMULATOR

FIG. 13

1900 PROVIDE AN ACCUMULATOR IN AN HVAC SYSTEM
1910 LOCATE ACCUMULATOR DOWNWIND OF HEATED AIR FROM A CONDENSER
1920 ALLOW HEATED AIR TO WARM ACCUMULATOR
1930 MAINTAIN ACCUMULATOR AT 5% TO 20% ABOVE THE LIQUID SATURATION TEMPERATURE
1940 REFRIGERANT FLOWS TO ACCUMULATOR WHEN PRESSURE SPIKES WITHIN THE HVAC SYSTEM
2000

PROVIDE A CONDENSER WITHIN AN HVAC SYSTEM

2010

DOWNWIND FROM CONDENSER PROVIDE AN ACCUMULATOR FLUIDLY COUPLED TO THE REFRIGERANT WITHIN THE HVAC SYSTEM

2020

ALLOW DOWNWIND AIR TO HEAT THE ACCUMULATOR TO 5% TO 20% ABOVE THE LIQUID SATURATION TEMPERATURE

2030

REFRIGERANT FLOWS INTO THE ACCUMULATOR WHEN PRESSURE RISES ABOVE A SET LIMIT WITHIN THE HVAC SYSTEM

2040

FIG. 14
2100

provide an accumulator liquidly coupled to a refrigerant line, wherein excess pressure causes refrigerant to accumulate in the accumulator

2110

heat the accumulator to 5% to 20% above the liquid saturation temperature during normal operation, causing accumulated refrigerant to return to the line

2120

fig. 15

2200

provide an accumulator liquidly coupled to a refrigerant line in an HVAC system, wherein excess pressure causes refrigerant to accumulate therein

2210

heat the accumulator above the liquid saturation temperature during normal operation of the HVAC system, such that accumulated refrigerant is returned to the refrigerant line

2220

power down the HVAC system, causing refrigerant to accumulate in the accumulator

2230

fig. 16
SYSTEM AND METHOD TO OPTIMIZE EFFECTIVENESS OF LIQUID LINE ACCUMULATOR

TECHNICAL FIELD

[0001] The present disclosure is directed to HVAC systems, and more particularly to systems and methods for relieving high pressure within HVAC systems using micro-channel condensers.

BACKGROUND OF THE INVENTION

[0002] The buildup of refrigerant pressure in heating, ventilation and air conditioning (HVAC) systems is a common problem. One previous solution has been to limit refrigerant within an HVAC system. However, this solution leads to a loss in efficiency.

[0003] Another solution is an accumulator/compensator. In some embodiments the accumulator/compensator can provide an extra reservoir for refrigerant. When pressure spikes within the HVAC system the reservoir can house refrigerant and relieve the extra pressure. Examples of accumulators/compensators are described in U.S. patent application Ser. No. 14/706,945, entitled “Refrigerant Pressure Relief in HVAC Systems,” filed May 7, 2015, and U.S. patent application Ser. No. 14/279,043, entitled “Liquid Line Charge Compensator,” filed May 15, 2014. The contents of the prior applications are hereby incorporated by reference with the same effect as if fully set forth herein.

BRIEF SUMMARY OF THE INVENTION

[0004] One embodiment of the current disclosure comprises a method of operating an HVAC system, the method comprising: providing an accumulator liquidly coupled to a refrigerant line of the HVAC system, wherein excess pressure in the refrigerant line causes refrigerant to accumulate in the accumulator, and heating the accumulator to between 5% and 20% above the liquid saturation temperature during normal operation of the HVAC system such that refrigerant is returned to the refrigerant line.

[0005] Another embodiment comprises a method of operating an HVAC system comprising: providing an accumulator liquidly coupled to a refrigerant line in the HVAC system, wherein excess pressure in the refrigerant line causes refrigerant to accumulate in the accumulator, and heating the accumulator above the liquid saturation temperature during normal operation of the HVAC system such that accumulated refrigerant is returned to the refrigerant line; and powering down the HVAC system, wherein powering down the HVAC system causes refrigerant to accumulate in the accumulator.

[0006] Another embodiment comprises an HVAC system comprising: an accumulator, the accumulator liquidly coupled with the refrigerant line of the HVAC system, wherein excess pressure in the refrigerant line causes refrigerant to accumulate in the accumulator, and wherein powering down the HVAC system causes refrigerant to accumulate in the accumulator, and a heat source, the heat source operable to heat the accumulator to 5% to 20% above the liquid saturation temperature during normal operation of the HVAC system, and thereby cause accumulated refrigerant to return to the refrigerant line.

[0007] The foregoing has outlined rather broadly the features and technical advantages of the present invention in order that the detailed description of the invention that follows may be better understood. Additional features and advantages of the invention will be described hereinafter which form the subject of the claims of the invention. It should be appreciated by those skilled in the art that the conception and specific embodiment disclosed may be readily utilized as a basis for modifying or designing other structures for carrying out the same purposes of the present invention. It should also be realized that those skilled in the art that such equivalent constructions do not depart from the spirit and scope of the invention as set forth in the appended claims. The novel features which are believed to be characteristic of the invention, both as to its organization and method of operation, together with further objects and advantages will be better understood from the following description when considered in connection with the accompanying figures. It is to be expressly understood, however, that each of the figures is provided for the purpose of illustration and description only and is not intended as a definition of the limits of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] For a more complete understanding of the present invention, reference is now made to the following descriptions taken in conjunction with the accompanying drawings, in which:

[0009] FIGS. 1A-1B are diagrams of system embodiments of the present disclosure.

[0010] FIGS. 2A-2B are diagrams of accumulator embodiments under the present disclosure.

[0011] FIG. 3 is a flow-chart diagram of a method embodiment under the present disclosure.

[0012] FIG. 4 is a diagram of an accumulator embodiment under the present disclosure.

[0013] FIG. 5 is a diagram of an accumulator embodiment under the present disclosure.

[0014] FIG. 6 is a diagram of a system embodiment under the present disclosure.

[0015] FIG. 7 is a diagram of a system embodiment under the present disclosure.

[0016] FIG. 8 is a diagram of a system embodiment under the present disclosure.

[0017] FIG. 9 is a diagram of a system embodiment under the present disclosure.

[0018] FIG. 10 is a diagram of a system embodiment under the present disclosure.

[0019] FIG. 11 is a graph of experimental data related to the present disclosure.

[0020] FIG. 12 is a flow-chart diagram of a method embodiment under the present disclosure.

[0021] FIG. 13 is a flow-chart diagram of a method embodiment under the present disclosure.

[0022] FIG. 14 is a flow-chart diagram of a method embodiment under the present disclosure.

[0023] FIG. 15 is a flow-chart diagram of a method embodiment under the present disclosure.

[0024] FIG. 16 is a flow-chart diagram of a method embodiment under the present disclosure.

DETAILED DESCRIPTION OF THE INVENTION

[0025] The present disclosure can provide a system and method for relieving pressure buildup within an HVAC...
system, storing refrigerant when a system is powered down, and returning refrigerant to the HVAC system upon startup. An accumulator/compensator apparatus can house refrigerant during pressure spikes and during periods in which an HVAC system is powered down. The present disclosure relates to U.S. patent application Ser. No. 14/706,945, entitled “Refrigerant Pressure Relief in HVAC Systems,” filed May 7, 2015, and U.S. patent application Ser. No. 14/279,043, entitled “Liquid Line Charge Compensator,” filed May 15, 2014, which are incorporated herein by reference.

[0026] FIG. 1A depicts an HVAC system 100 with a liquid line charge accumulator/compensator apparatus 101. The HVAC system 100 may comprise an indoor unit 102, an outdoor unit 104, and a controller 105. The indoor unit 102 may reside inside a structure to be heated or cooled, such as a building or refrigerator. Similarly, the outdoor unit 104 may reside outside the structure. Generally, residential HVAC systems may operate with this particular combination of an indoor unit and an outdoor unit. Besides residential HVAC systems, the combination may be used in other applications such as commercial rooftop package units and refrigeration.

[0027] In the absence of high discharge pressure, the HVAC system 100 may operate conventionally. A continuous flow of refrigerant charge may travel in a loop, called a vapor compression cycle, through the HVAC system 100. A compressor 106 may compress the liquid refrigerant 100 in gas vapor form and may discharge the refrigerant vapor through a discharge line 108. The compressed refrigerant gas vapor may enter a reversing valve 110. The reversing valve 110 may change between a cooling configuration, shown by solid lines, and a heating configuration, shown by dashed lines.

[0028] In the cooling configuration, the refrigerant may flow from the reversing valve 110 to an outdoor heat exchanger 112. The refrigerant may flow through the outdoor heat exchanger 112, releasing heat into the outdoor air. The refrigerant may condense into a liquid as it flows through the outdoor heat exchanger 112. From the outdoor heat exchanger 112, the liquid refrigerant may flow through a liquid line 114.

[0029] The liquid line 114 may have an expansion device 116A and an expansion device 116B. Either the expansion device 116A or the expansion device 116B may reduce the pressure of the refrigerant by expanding the liquid refrigerant flowing through the liquid line 114. Due to check valves or the like, the expansion device 116A may only act on refrigerant flowing toward the outdoor heat exchanger 112, and the expansion device 116B may only act on refrigerant flowing toward an indoor heat exchanger 118.

[0030] When the HVAC system 100 is in the cooling configuration, liquid refrigerant may bypass the expansion device 116A and may continue toward the expansion device 116B. The expansion device 116B may reduce the pressure of the liquid refrigerant flowing through it. The liquid refrigerant may flow through the indoor heat exchanger 118, absorbing heat from the structure and evaporating into a gas vapor. The refrigerant may flow to the reversing valve 110, where it may be directed through a suction line 120 and back into the compressor 106 to be compressed again.

[0031] In the heating configuration, the refrigerant may flow from the reversing valve 110 to the indoor heat exchanger 118. The refrigerant may flow through the indoor heat exchanger 118, releasing heat into a structure. The refrigerant may condense into a liquid as it flows through the indoor heat exchanger 118. From the indoor heat exchanger 118, the liquid refrigerant may flow through the liquid line 114. The liquid refrigerant may bypass the expansion device 116B and may flow to the expansion device 116A. The expansion device 116A may reduce the pressure of the liquid refrigerant flowing through it. The refrigerant may flow through the outdoor heat exchanger 112, absorbing heat from the outdoor air and evaporating into a gas vapor. The refrigerant may flow to the reversing valve 110, where it may be directed through the suction line 120 and back into the compressor 106 to be compressed again.

[0032] The outdoor heat exchanger 112 may be called an outdoor coil. The indoor heat exchanger 118 may be called an indoor coil. During cooling, the outdoor heat exchanger 112 may be called a condenser and the indoor heat exchanger 118 may be called an evaporator. During heating, the outdoor heat exchanger 112 may be called the evaporator and the indoor heat exchanger 118 may be called the condenser. The expansion devices 116A and 116B may be expansion valves.

[0033] According to the embodiment shown, the HVAC system 100 may be capable of both heating and cooling operation. An HVAC system that can perform both may be called a heat pump. An air conditioner or heater may be substituted for the HVAC system 100. An air conditioner may be an HVAC system which is capable of only cooling. A heater may be an HVAC system which is capable of only heating.

[0034] In an HVAC system that is capable of either heating or cooling, but not both, the reversing valve 110 may be unnecessary since the direction of refrigerant flow does not reverse. The expansion device 116A may also be unnecessary in an air conditioner because refrigerant does not flow through the liquid line 114 toward the outdoor heat exchanger 112. Likewise, the expansion device 116B may be unnecessary in a heater because refrigerant does not flow through the liquid line 114 toward indoor heat exchanger 118.

[0035] The charge compensator apparatus 101 may comprise a compensator line 122, a charge compensator reservoir 124, and a compensator valve 126. The charge compensator apparatus 101 may be located between the expansion device 116A and the expansion device 116B. The compensator line 122 may connect the liquid line 114 to the charge compensator reservoir 124. The connection 122A may be the connection between the compensator line 122 and the liquid line 114. The connection 122B may be the connection between the compensator line 122 and the charge compensator reservoir 124. The charge compensator reservoir 124 may be a tank which holds excess refrigerant. The charge compensator reservoir 124 may be made of steel. The connection 122B may be vertically higher than the connection 122A, so that gravity may drain refrigerant from the charge compensator reservoir 124 into the liquid line 114.

[0036] The compensator valve 126 may be positioned on the compensator line 122. The compensator valve 126 may be opened, allowed the flow of refrigerant through the compensator line 122, or closed, to block the flow of refrigerant through the compensator line 122. The compensator valve 126 may be a solenoid valve.

[0037] When the compensator valve 126 is open, relatively high pressure in the liquid line 114 may cause refrig-
erant to migrate into the charge compensator reservoir 124. Lower pressure in the liquid line 114 may cause refrigerant to drain from the charge compensator reservoir 124 into the liquid line 114. The compensator valve 126 may be closed to keep the refrigerant from draining.

[0038] The controller 105 may operate the compensator valve 126. Where the compensator valve 126 is a solenoid valve, the controller 105 may send current through the compensator valve 126 directly or send a signal that causes current to be sent through the compensator valve 126. The controller 105 may be a unit controller that controls the overall operation of the indoor unit 102 and the outdoor unit 104, or may be a separate controller that only controls when the compensator valve 126 opens and closes.

[0039] In the embodiment of FIG. 1A, the charge compensator apparatus 101 is shown inside the outdoor unit 104. More generally, FIG. 1A shows the charge compensator reservoir 124 in the ambient environment of the outdoor heat exchanger 112. As shown in the embodiment of FIG. 1B, the charge compensator reservoir 124 may additionally, or alternatively, be located inside the indoor unit 102. More generally, FIG. 1B shows the charge compensator reservoir 124 in the ambient environment of the indoor heat exchanger 118.

[0040] During cooling, the charge compensator reservoir 124 in FIG. 1A may be in the ambient environment of the condenser. During heating, the charge compensator reservoir 124 in FIG. 1A may be in the ambient environment of the evaporator. During cooling, the charge compensator reservoir 124 in FIG. 1B may be in the ambient environment of the evaporator. During heating, the charge compensator reservoir 124 in FIG. 1B may be in the ambient environment of the condenser.

[0041] The location of the charge compensator reservoir 124 in FIG. 1A may be upstream or downstream of the outdoor heat exchanger 112. The location of the charge compensator reservoir 124 in FIG. 1B may be upstream or downstream of the indoor heat exchanger 118. The charge compensator reservoir 124 is “upstream” of a heat exchanger when air flows past the charge compensator reservoir 124 before flowing past the heat exchanger. The charge compensator reservoir 124 is “downstream” of a heat exchanger when air flows past the charge compensator reservoir 124 after flowing past the heat exchanger.

[0042] The location of the charge compensator reservoir 124 may affect the temperature of the charge compensator reservoir. When the charge compensator reservoir 124 is hotter, more pressure may be needed in the liquid line 114 to fill the charge compensator reservoir 124, but less pressure may be needed in the liquid line 114 to drain the charge compensator reservoir 124. The ambient environment of the condenser is generally hotter than the ambient environment of the evaporator. Air flowing past the condenser may be additionally heated, while air flowing past the evaporator may be additionally cooled. Generally speaking, the possible locations of the charge compensator reservoir 124 may be, in order from hottest to coldest, (1) in the ambient environment of the condenser, downstream of the condenser, (2) in the ambient environment of the condenser, upstream of the condenser, (3) in the ambient environment of the evaporator, upstream of the evaporator, and (4) in the ambient environment of the evaporator, downstream of the evaporator.

[0043] The desired location of the charge compensator apparatus 101 may be application dependent. The desired location of the charge compensator reservoir 124 may depend on pressure conditions in the liquid line 114 or be based on a need of a particular HVAC system to have a certain fill or drain rate. The desired location of the charge compensator reservoir 124 may be where the pressure in the charge compensator reservoir 124 would be the most consistent. The ambient temperature of the environment surrounding the charge compensator reservoir 124 may affect consistent state pressure.

[0044] Regardless of where the charge compensator reservoir 124 is located, the rest of the charge compensator apparatus 101 may be in the same location. The charge compensator apparatus 101 may be located between the expansion device 116A and the expansion device 116B, and the charge compensator apparatus 101 may be on the liquid line 114.

[0045] Referring to FIG. 2A, the configuration 200A may be a configuration of the charge compensator apparatus 101 allowing for filling or draining of the charge compensator reservoir 124. In the configuration 200A, the compensator valve 126 may be open, as shown by the dotted lines. With the compensator valve 126 open, the refrigerant 202 in the liquid line 114 may enter or leave the charge compensator reservoir 124, depending on the pressure in the liquid line 114. High pressure in the liquid line 114 may cause the refrigerant 202 in the liquid line 114 to migrate into the charge compensator reservoir 124. The refrigerant 202 entering the charge compensator reservoir 124 may cause a reduction of the pressure in the vapor compression cycle and may prevent a high discharge pressure trip.

[0046] When the pressure in the liquid line 114 decreases sufficiently, or pressure in the reservoir 124 increases sufficiently, or some combination thereof, the liquid refrigerant 202 within the charge compensator reservoir 124 may gradually flow back down the compressor line 122 due to gravity, past the compressor valve 126, and back into the liquid line 114. Because the configuration 200A depends on gravity, the connection 122B should be placed vertically higher than the connection 122A, so that gravity may drain refrigerant from the charge compensator reservoir 124 into the liquid line 114. In FIG. 2A, the liquid refrigerant 202 may flow through the liquid line 114 from left to right during cooling and from right to left during heating.

[0047] Referring to FIG. 2B, the configuration 200B may be a configuration of the charge compensator apparatus 101 which may hold the refrigerant 202 within the charge compensator reservoir 124. In the configuration 200B, the compensator valve 126 may be closed. The refrigerant 202 in the charge compensator reservoir 124 may be kept in the charge compensator reservoir 124 by the closed compensator valve 126.

[0048] In an embodiment, the compressor 106 of FIGS. 1A & 1B may be configured for tandem operation as part of a tandem compressor group. A tandem compressor group may comprise two or more compressors. In tandem compressor operation, all of the tandem compressors may run simultaneously, a portion of the tandem compressors may operate, or only one tandem compressor may operate at a time. When a tandem compressor group operates using less than all of the tandem compressors, the tandem compressor group may be operating at part load. When a tandem compressor group operates using all of the tandem compressors, the tandem compressor group may be operating at full load. Full load is generally a response to high outdoor
ambient conditions, such as a 95°F outdoor ambient temperature, for example. When a tandem compressor starts all the compressors simultaneously, a higher amount of compression is created in a shorter amount of time compared to using only one compressor or the starting of a variable speed compressor at lower speed.

**0049** An HVAC system comprising a tandem compressor group often also comprises a microchannel condenser because together they deliver a high Integrated Energy Efficiency Ratio (IEER). Part load efficiency is important because the tandem compressor group is typically operated in part load unless there are high ambient conditions. In such an HVAC system, the outdoor heat exchanger 112 and/or the indoor heat exchanger 118 may be microchannel heat exchangers. During air conditioning, the outdoor heat exchanger 112 may be a microchannel condenser and the indoor heat exchanger 118 may be a microchannel evaporator. During heating, the indoor heat exchanger 118 may be a microchannel condenser and the outdoor heat exchanger 112 may be a microchannel evaporator.

**0050** When in part load conditions, an HVAC system implemented with a tandem compressor group may be optimized when there is additional refrigerant charge, typically one to two pounds, over the optimum refrigerant charge for full load conditions. When an HVAC system is optimized for part load conditions but operating in full load conditions, the additional refrigerant charge in the HVAC system may cause a spike in discharge pressure. The spike in discharge pressure may lead to a high discharge pressure trip. High discharge pressure trips can also occur at part load conditions.

**0051** FIG. 3 depicts one method embodiment 300 for reducing discharge pressure in an HVAC system at startup of one or more system compressors. In an embodiment, the method 300 may be performed by the HVAC system 100 implemented with the charge compensator apparatus 101, as described above. At step 302, the compressor valve may be opened. At step 304, liquid refrigerant may enter the liquid line as part of vapor compression cycle operation. At step 306, the liquid refrigerant may enter the charge compensator reservoir due to high pressure in the liquid line. At step 308, the liquid refrigerant may leave the charge compensator reservoir due to gravity when the pressure in the liquid line decreases. As discussed below, a heat source may aid in the spread of refrigerant from the accumulator/compensator to the system.

**0052** Referring now to FIG. 4, a first pressure relief apparatus 600 is shown. The first pressure relief apparatus 600 may be implemented within the HVAC system 100 of FIGS. 1A and 1B for reducing refrigerant pressures. According to the embodiment shown, the first pressure relief apparatus 600 may comprise a receptacle 602 and a lower relief tube 604. In alternative embodiments, the first pressure relief apparatus 600 may include fewer, additional, or different components than those shown. In an embodiment, the first pressure relief apparatus 600 may comprise one or more functions, components, and characteristics substantially the same as, or similar to, those of the charge compensator apparatus 101, described above. Further, in an embodiment, the first pressure relief apparatus 600 may operate to reduce the HVAC system 100 refrigerant pressure, or pressures, substantially in the manner described above in reference to the charge compensator apparatus 101 while the charge compensator apparatus 101 is in the configuration 200A. The receptacle 602 may include an open internal volume which may be accessed via one or more openings through a surface of the receptacle 602. The receptacle 602 may receive high temperature, high pressure gaseous phase or liquid phase refrigerant. In an embodiment, therefore, the receptacle 602 may be composed of a material capable of withstand high internal pressures exerted by the HVAC system 100 refrigerant that may be contained within the receptacle. As shown, the first pressure relief apparatus 600 may include the lower relief tube 604, which may comprise a length of tubing for operatively connecting the receptacle 602 to the refrigerant piping of the HVAC system 100. The lower relief tube 604 may provide a means of access through which the HVAC system refrigerant may migrate into, or drain from, the receptacle 602 in response to pressure changes of refrigerant within the HVAC system 100. The lower relief tube 604 may be a substantially straight section of tubing having a uniform profile. In alternative embodiments, the lower relief tube 604 may have a configuration different from that shown in the embodiment of FIG. 4. In an alternative embodiment, for example, the lower relief tube 604 may have a non-uniform profile and/or may be configured to extend along a path having one or more bent or curved sections. In an embodiment, as shown, the lower relief tube 604 may include the lower joint 606 and the upper joint 608 which may be disposed at opposite ends of the lower relief tube 604. In an alternative embodiment, the lower relief tube 604 may include additional upper and/or lower joints 606, 608. During HVAC system 100 operation, including at start up, the first pressure relief apparatus 600 may operate to reduce the HVAC system 100 refrigerant pressure, or pressures. Specifically, according to the embodiment of FIG. 4, a portion of the HVAC system 100 refrigerant may migrate into the receptacle 602 via the lower relief tube 604 at startup, or at any time during the HVAC system 100 operation, in response to high refrigerant pressure, or pressures, within the HVAC system 100. The first pressure relief apparatus 600 may reduce refrigerant pressures within the HVAC system 100 by allowing for a decrease in the quantity of active refrigerant within the HVAC system 100.

**0053** Referring now to FIG. 5, a second pressure relief apparatus 700 for reducing refrigerant pressure within an HVAC system is shown. The second pressure relief apparatus 700 may be implemented within the HVAC system 100. According to the embodiment shown, the second pressure relief apparatus 700 may comprise a receptacle 702, a lower relief tube 704, and a valve 710. In alternative embodiments, the second pressure relief apparatus 700 may include fewer, additional, or different components than those shown. In an embodiment, the second pressure relief apparatus 700 may comprise one or more features, functions, and/or characteristics substantially the same as, or similar to, those of the first pressure relief apparatus 600, as described above, and may be additionally provided with the valve 710. Specifically, the receptacle 702 of the second pressure relief apparatus 700 may comprise a container for receiving high pressure refrigerant from the HVAC system 100 and may comprise one or more features, functions, and/or characteristics substantially the same as, or similar to, those of the receptacle 602. Further, the lower relief tube 704 may comprise a length of tubing for connecting the receptacle 702 to the piping of the HVAC system 100 and may comprise one or more features, functions, and/or characteristics substantially the same as, or similar to, those of the
lower relief tube 604. Additionally, or alternatively, in an embodiment, the second pressure relief apparatus 700 may comprise one or more features, functions, and/or characteristics substantially the same as, or similar to, those of the liquid line charge compensator apparatus 101, described above. Specifically, the second pressure relief apparatus 700 may include the valve 710 which may couple to the lower relief tube 704 for selectively permitting, or preventing, active refrigerant from accessing the second pressure relief apparatus 700. The valve 710 may be closed to prevent active refrigerant from migrating into the receptacle 702 or to prevent inactive refrigerant from draining from the receptacle 702. In an embodiment, the valve 710 may comprise one or more features, functions, and/or characteristics substantially the same as, or similar to, those of the valve 310 of the liquid line charge compensator apparatus 101. In an embodiment, the controller 105 may control the valve 710, switching the valve 710 between open and, closed positions. The valve 710 may be operably coupled to the controller 105 via a wired or wireless connection. The controller 105 may control the valve 710 position in response to sensed, or detected, conditions within the HVAC system 100. In an embodiment, the valve 710 may be a solenoid valve. Alternatively, in an embodiment, the valve 710 may be a check valve, a flow control valve, a three-way valve, a four way valve, or the like.

[0054] An accumulator/compensator under the present disclosure can be placed or located in a variety of locations within an HVAC system. The accumulator can also take a variety of shapes and sizes.

[0055] In some embodiments of the present disclosure it will be desirable to supply a source of heat to the accumulator. While it is beneficial for refrigerant to reside in the accumulator/compensator when an HVAC system is powered down, there is a need for refrigerant to spread throughout the system upon being powered up. The speed with which refrigerant is needed throughout the system will depend on various factors such as the system capacity, type of refrigerant, refrigerant phase, system size, load, and other factors. There may be a need for refrigerant to exit the accumulator immediately, or in other embodiments, at an orderly rate desired by a user(s). Depending on the user’s needs the amount of heat may differ depending on the individual HVAC system with its unique load, refrigerant, geometry, and other factors. The present disclosure includes embodiments with various heat sources. It will be advantageous, and economical, to heat the accumulator with heat generated by other components within the HVAC system. Such embodiments may entail the placement of the accumulator in various locations within the HVAC system, depending on the individual layout of each HVAC system. Other embodiments may require an independently powered and installed heat source. During normal operation, it is beneficial to have the accumulator kept at a temperature higher than the liquid saturation temperature but less than a discharge temperature. Normal operation begins usually 10 to 20 minutes (in some cases it can take more or less time) after the HVAC system is started up. During startup the refrigerant may still be consolidated in certain areas of the HVAC system, and may not be flowing at the desired temperatures or speeds.

[0056] Two possible sources of heat, from within an HVAC system, are the downwind air from a condenser and the inlet refrigerant line for a condenser. Refrigerant enters a condenser at a, comparatively, high temperature and likely in a gaseous state. The refrigerant condenses as it passes through the condenser, taking a liquid state, and dropping in temperature. The heat lost by the refrigerant enters the air passing around the condenser thereby raising the air’s temperature. Another possible location for an accumulator could be near the outlet line of an evaporator. For HVAC systems that can reverse flow and change between heating and cooling cycles, a plurality of accumulators may be installed including valves dictating which accumulator gets used under which operating conditions.

[0057] FIG. 6 shows a possible embodiment of an accumulator and condenser combination 1200 within an HVAC system. Accumulator 1210 is capable of receiving refrigerant from lines 1212, 1214. Lines 1212, 1214 can each serve as either an inlet or outlet depending on the specific embodiment or installation of the system. In some embodiments only one line will be needed. Accumulator 1210 receives refrigerant from another part of the HVAC system and will likely be placed somewhere between a condenser and an evaporator, though other locations are possible. When the HVAC system is powered down the refrigerant collects in accumulator 1210. Upon powering up, the user needs refrigerant 1250 to exit the accumulator and spread throughout the HVAC system. Heating the refrigerant will help it spread more quickly so the system, either in a gaseous or liquid state. In the embodiment displayed in FIG. 6 accumulator 1210 can receive heat from several sources when the HVAC system is powered up. One source can be the inlet line 1222 for condenser 1220. Refrigerant passing through inlet 1222 is at a high temperature compared to the outlet 1224. The accumulator 1210 can be placed such that it can receive radiated heat from the passing liquid. In some embodiments accumulator 1210 may even physically contact inlet line 1222. Furthermore, in this embodiment, accumulator 1210 will be heated by the passing air 1230 that has passed through condenser 1220 and therefore is heated as refrigerant condenses and loses heat to the passing air 1230. For heat from the condenser, the amount of heat can be controlled by the area of the condenser that the accumulator is placed next to. There will be more heat at entrance side and less heat at the exit side. The heat received by accumulator 1210 causes the refrigerant 1250 stored therein to increase in temperature, possibly taking on a gaseous state, and flow more easily and quickly through the HVAC system. There can be a valve on or near the accumulator that may open when the HVAC system is powered on, allowing refrigerant to flow into the HVAC system. The valve may open completely, or partially, to let refrigerant flow at a given rate. Furthermore, gravity can be used to help pull refrigerant from the accumulator—placing the accumulator in a high position relative to other elements of an HVAC system will help cause refrigerant to flow.

[0058] Another embodiment may comprise an accumulator that is heated by downwind air from a condenser but not by the input refrigerant line for the condenser, such as in FIG. 7. As shown, accumulator 1310 is located away from input line 1322 but is still in the path of air 1320 after it passes through condenser 1320 and is heated. The embodiment of FIG. 7 would likely be used when less heat is needed than the embodiment of FIG. 6.

[0059] Another embodiment may comprise an accumulator that is heated by refrigerant entering a condenser but not by heated air downwind from a condenser. Such an embodi-
ment is shown in FIG. 8. Accumulator 1410 is placed near inlet line 1422 that provides hot refrigerant to condenser 1420. But accumulator 1410 is not exposed to the heated air 1430 after passing through condenser 1420. In certain situations, this setup may heat the refrigerant 1450 within accumulator 1410 according to the user’s preferences better than other setups.

[0060] FIG. 9 shows an embodiment wherein an accumulator 1510 is located near the discharge line of an evaporator coil 1520. The HVAC system 1500 can include an evaporator coil 1520, accumulator 1510, condenser 1530, compressor 1540 and other components as needed.

[0061] FIG. 10 shows an embodiment of an HVAC system 1600 incorporating an accumulator 1610 that is heated by a heating unit 1660. Heating unit 1660 can be connected to a controller 1670. Controller 1670 can be connected to other components of system 1600 and can comprise the general purpose controller for the system 1600. Upon startup, heating unit 1660 can apply heat directly to accumulator 1610 housing refrigerant 1650, causing refrigerant 1650 to spread throughout HVAC system 1600 and likely to change to a gas state to facilitate such spreading. Embodiments as in FIG. 10 may be necessary when other locations within the HVAC system 1600 do not supply the proper amount of heat for refrigerant 1650 to spread through system 1600 quickly enough or at the proper rate. This embodiment may also be more amenable to retrofitting solutions. The heating unit 1660 may be independently powered and not necessarily related to other components of the HVAC system. Types of heating units can include a heating pad, resistance heating wire or other heating technologies.

[0062] Through testing of embodiments of the present disclosure it has been discovered what ranges of temperatures are most beneficial to the operation of the disclosed embodiments. Refrigerant should be hotter than the ambient temperature, and above a liquid saturated temperature, but below a discharge temperature of a system. FIG. 11 shows a graph reflecting the results of these experiments. Measurements were taken at various ambient temperatures (OD Temp). The lines on the graph reflect the OD temperature 1710, the liquid saturation temperature 1720, the accumulator temperature 1730, the discharge temperature 1740, and the optimum range 1738. The x-axis 1760 reflects OD temperature and the y-axis 1750 reflects refrigerant temperature. As shown, the ideal temperature for the accumulator, during normal operation, can have only 5 degrees above the liquid saturation temperature (or roughly ±5-10 percent above the liquid saturation temperature). At this temperature the accumulator will stay empty. If the accumulator gets too hot (approximately 20 degrees F. above liquid saturation temperature) then liquid will not fill the accumulator during a high pressure spike condition. Generally, the optimal range is about 5% to 20% above the liquid saturation temperature.

[0063] When the HVAC system is powered off the refrigerant and accumulator will likely fall to less than or equal to the outdoor or ambient temperature. This causes charge to flow into the accumulator, thereby helping to ease system startups and avoid discharge pressure spikes. Upon startup, accumulator temperature should reach optimum level in 10 minutes or less, though it may take up to 20 or 30 minutes. Longer times will affect performance as it causes extended operation at less than ideal charge levels which prevents sub-cooling of liquid refrigerant.

[0064] FIGS. 12-16 display various method embodiments of the present disclosure.

[0065] FIG. 12 shows a method 1800. An accumulator is provided in an HVAC system 1810. The accumulator is maintained at 5% to 20% above the liquid saturation temperature during normal operation (typically 5-20 minutes after startup) 1820. And during pressure spikes the refrigerant flows into the accumulator 1830.

[0066] FIG. 13 shows a method 1900. An accumulator is provided in an HVAC system 1910. The accumulator is located downwind of heated air from a condenser 1920. The heated air is allowed to heat the accumulator 1930. The accumulator is maintained at 5% to 20% above the liquid saturation temperature 1940. Refrigerant flows into the accumulator when pressure spikes within the HVAC system 1950.

[0067] FIG. 14 shows a method 2000. A condenser is provided within an HVAC system 2010. An accumulator is provided downwind from the condenser that is fluidly coupled to the refrigerant within the HVAC system 2020. Air from the condenser is allowed to heat the accumulator to 5% to 20% above the liquid saturation temperature 2030. Refrigerant flows into the accumulator when pressure rises above a set limit within the HVAC system 2040.

[0068] FIG. 15 shows a method embodiment of the present disclosure 2100. An accumulator liquidly coupled to a refrigerant line of the HVAC system is provided, wherein excess pressure in the refrigerant line causes refrigerant to accumulate in the accumulator 2110. The accumulator is heated to between 5% and 20% above the liquid saturation temperature during normal operation of the HVAC system, such that refrigerant is returned to the refrigerant line 2120.

[0069] FIG. 16 shows a method embodiment of the present disclosure 2200. An accumulator is provided that is liquidly coupled to a refrigerant line in the HVAC system, wherein excess pressure in the refrigerant line causes refrigerant to accumulate in the accumulator 2210. The accumulator is heated above the liquid saturation temperature during normal operation of the HVAC system such that accumulator fluidly refrigerant is returned to the refrigerant line 2220. The HVAC system is powered down, wherein powering down the HVAC system causes refrigerant to accumulate in the accumulator 2230.

[0070] Although the present invention and its advantages have been described in detail, it should be understood that various changes, substitutions and alterations can be made herein without departing from the spirit and scope of the invention as defined by the appended claims. Moreover, the scope of the present application is not intended to be limited to the particular embodiments of the process, machine, manufacture, composition of matter, means, methods and steps described in the specification. As one of ordinary skill in the art will readily appreciate from the disclosure of the present invention, processes, machines, manufacture, compositions of matter, means, methods, or steps, presently existing or later to be developed that perform substantially the same function or achieve substantially the same result as the corresponding embodiments described herein may be utilized according to the present invention. Accordingly, the appended claims are intended to include within their scope such processes, machines, manufacture, compositions of matter, means, methods, or steps.
What is claimed is:

1. A method of operating an HVAC system, the method comprising:
   providing an accumulator liquidly coupled to a refrigerant line of the HVAC system, wherein excess pressure in the refrigerant line causes refrigerant to accumulate in the accumulator; and
   heating the accumulator to between 5% and 20% above the liquid saturation temperature during normal operation of the HVAC system, such that refrigerant is returned to the refrigerant line.
2. The method of claim 1 wherein the heating of the accumulator is provided by placing the accumulator near the inlet line to a condenser.
3. The method of claim 1 wherein the heating of the accumulator is provided by placing the accumulator near the outlet line of an evaporator.
4. The method of claim 1 wherein the heating of the accumulator is provided by placing the accumulator in the path of heated air received from a condenser.
5. The method of claim 1 wherein the heating of the accumulator is provided by a heating element.
6. The method of claim 1 wherein the heating of the accumulator is also placed near the inlet line to a condenser.
7. The method of claim 1 wherein a valve controls whether refrigerant flows into or out of the accumulator.
8. The method of claim 7 wherein the valve is a solenoid valve.
9. A method of operating an HVAC system comprising:
   providing an accumulator liquidly coupled to a refrigerant line in the HVAC system, wherein excess pressure in the refrigerant line causes refrigerant to accumulate in the accumulator;
   heating the accumulator above the liquid saturation temperature during normal operation of the HVAC system such that accumulated refrigerant is returned to the refrigerant line; and
   powering down the HVAC system, wherein powering down the HVAC system causes refrigerant to accumulate in the accumulator.
10. The method of claim 9 wherein the heating of the accumulator is provided by placing the accumulator near the inlet line to a condenser.
11. The method of claim 9 wherein the heating of the accumulator is provided by placing the accumulator near the outlet line of an evaporator.
12. The method of claim 9 wherein the heating of the accumulator is provided by placing the accumulator in the path of heated air received from a condenser.
13. The method of claim 9 wherein the heating of the accumulator is provided by a heating element.
14. The method of claim 12 wherein the accumulator is also placed near the inlet line to a condenser.
15. The method of claim 9 wherein a valve controls whether refrigerant flows into or out of the accumulator.
16. The method of claim 15 wherein the valve is a solenoid valve.
17. An HVAC system comprising:
   an accumulator, the accumulator liquidly coupled with the refrigerant line of the HVAC system, wherein excess pressure in the refrigerant line causes refrigerant to accumulate in the accumulator, and wherein powering down the HVAC system causes refrigerant to accumulate in the accumulator; and
   a heat source, the heat source operable to heat the accumulator to 5% to 20% above the liquid saturation temperature during normal operation of the HVAC system, and thereby cause accumulated refrigerant to return to the refrigerant line.
18. The HVAC system of claim 17 wherein the heat source comprises air heated by a condenser.
19. The HVAC system of claim 17 wherein the heat source comprises the inlet line to a condenser.
20. The HVAC system of claim 17 wherein the heat source comprises an outlet line from an evaporator.

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