MULTI-INJECTION CONDENSATION FOR REFRIGERATION SYSTEMS AND METHOD

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APPL. NO.: 10/439,231

Filed: May 16, 2003

Publication Classification

Int. Cl. 7 .................................. F25B 41/00; F25B 49/00;
.............................................. F25B 1/00

U.S. Cl. ............................................ 62/197; 62/498

ABSTRACT

A condensing stage of a refrigeration system. The condensing stage comprises means for returning a portion of the refrigerant of the refrigeration system at a downstream end of the condensing stage in a high-pressure liquid state to an upstream end of the condensing stage, to mix the portion of refrigerant with refrigerant in the high-pressure gas state prior to being fed to the condensing stage so as to increase the amount of heat released by volume of refrigerant in the condensing stage.
Fig. 1
MULTI-INJECTION CONDENSATION FOR REFRIGERATION SYSTEMS AND METHOD

TECHNICAL FIELD

[0001] The present invention generally relates to refrigeration systems and, more particularly, to a condensation stage of a refrigeration system for reducing the compression stage pressure.

BACKGROUND ART

[0002] In order to be competitive, refrigeration-system vendors have downsized components of refrigeration systems to lower their prices while keeping their system capacity constant. Refrigeration systems lend themselves well to such downsizing, as the four major stages of refrigeration systems, namely the compression, the condensation, the expansion and the evaporation, can vary in size according to the capacity required.

[0003] In the condensation stage, heat exchange is performed between the refrigerant of the refrigeration system and a fluid such as ambient air, to remove both latent and sensible heat from the refrigerant. For instance, in the case of rooftop condensers, refrigerant is circulated in a heat exchanger, and air is circulated through the heat exchangers by one or more fans.

[0004] A given amount of heat must be released from the refrigerant at the condensation stage. During periods of maximal heat load, e.g., midday of summer days, condensers frequently operate at full capacity to enable the release of the given amount of heat from the refrigerant. Typically, the condensers are specified in view of the maximal loads. The condensers have a plurality of fans and a corresponding length of heat exchanger. In order to reduce the cost of refrigeration systems, vendors have downsized the condensers. As the given amount of heat must still be released in the warmer days, the inlet refrigerant pressure and temperature are increased to compensate for the downsizing of the condensers. The inlet refrigerant temperature increase will cause a greater temperature differential across the condenser and, thus, a greater amount of heat to be released.

[0005] Accordingly, refrigeration-system operators must operate the compressors of the compression stage at higher capacities in order to supply refrigerant at a suitable head pressure. This inefficient use of the compressors (i.e., below the optimal efficiency, which is normally attained at lower pressures) causes a substantial increase in the energy consumption and, thus, in the costs of operating the refrigeration systems. In other terms, refrigeration systems with smaller condensation units for a given capacity are sold for less than refrigeration systems having greater condensation units for that same given capacity, but are substantially more costly to operate, due to the inefficient use of the compressor.

SUMMARY OF INVENTION

[0006] Therefore, it is a feature of the present invention to provide a novel condensation stage for a refrigeration system.

[0007] It is a further feature of the present invention to provide a downsized refrigeration system which substantially overcomes the disadvantage of the prior art.

[0008] According to the above features, from a broad aspect, the present invention provides a condensing stage of a refrigeration system wherein a refrigerant goes through at least a compression stage, wherein said refrigerant is compressed to a high-pressure gas state to then reach said condensing stage through a high-pressure line, wherein said refrigerant in said high-pressure gas state is condensed at least partially to a high-pressure liquid state by releasing heat, to then reach an expansion stage, wherein said refrigerant in said high-pressure liquid state is expanded to a first low-pressure liquid state to then reach an evaporator stage, wherein said refrigerant in said first low-pressure liquid state is evaporated at least partially to a first low-pressure gas state by absorbing heat, to then return to said compression stage, said condensing stage comprising a refrigerant conveying line having an upstream end diverging from the high-pressure line to pass a portion of said refrigerant through said condensing stage, a downstream end of said refrigerant conveying line converging with the high-pressure line downstream of said upstream end of said refrigerant conveying line with respect to the high-pressure line to mix with refrigerant bypassing said refrigerant conveying line, prior to being fed to the condensing stage so as to increase the amount of heat released by volume of refrigerant in said condensing stage, and a valve in the high-pressure line between the upstream end and the downstream end of the refrigerant conveying line to control the amount of said portion of refrigerant.

[0009] According to a further broad feature of the present invention, there is provided a refrigeration system of the type wherein a refrigerant goes through at least a compression stage, wherein said refrigerant is compressed to a high-pressure gas state to then reach a condensing stage through a high-pressure line, wherein said refrigerant in said high-pressure gas state is condensed at least partially to a high-pressure liquid state by releasing heat, to then reach an expansion stage, wherein said refrigerant in said high-pressure liquid state is expanded to a first low-pressure liquid state to then reach an evaporator stage, wherein said refrigerant in said first low-pressure liquid state is evaporated at least partially to a first low-pressure gas state by absorbing heat, to then return to said compression stage, the refrigeration system comprising means for directing a portion of said refrigerant from a downstream end of said condensing stage in said high-pressure liquid state to an upstream end of said condensing stage, to mix said portion with refrigerant in said high-pressure gas state prior to being fed to the condensing stage so as to increase the amount of heat released by volume of refrigerant in said condensing stage.

[0010] According to a still further broad feature of the present invention, there is provided a method for increasing an amount of heat released by volume of refrigerant in a condensing stage of a refrigeration system of the type wherein said refrigerant goes through at least a compression stage, wherein said refrigerant is compressed to a high-pressure gas state to then reach said condensing stage, wherein said refrigerant in said high-pressure gas state is condensed at least partially to a high-pressure liquid state by releasing heat, to then reach an expansion stage, wherein said refrigerant in said high-pressure liquid state is expanded to a first low-pressure liquid state to then reach an evaporator stage, wherein said refrigerant in said first low-pressure liquid state is evaporated at least partially to a first low-
pressure gas state by absorbing heat, to then return to said compression stage, said method comprising the steps of: i) directing at least a portion of refrigerant to said condensing stage for a first pass; and ii) redirecting said portion of refrigerant upstream of said condensing stage to mix said portion of refrigerant with said refrigerant in said high-pressure gas state.

**BRIEF DESCRIPTION OF DRAWINGS**

[0011] A preferred embodiment of the present invention will now be described with reference to the accompanying drawings in which:

[0012] FIG. 1 is a block diagram of a refrigeration system having a condensation stage constructed in accordance with the present invention;

[0013] FIG. 2 is a schematic view of a refrigeration system constructed in accordance with a first embodiment of the present invention; and

[0014] FIG. 3 is a schematic view of a refrigeration system constructed in accordance with a second embodiment of the present invention.

**DESCRIPTION OF PREFERRED EMBODIMENTS**

[0015] Referring to the drawings, and more particularly to FIG. 1, a refrigeration system in accordance with the present invention is generally shown at 10, in a block diagram illustrating the interrelation of a refrigeration system. The refrigeration system 10 has a compression stage 12, a condensation stage 14, an expansion stage 16, and an evaporation stage 18. Refrigerant lines interconnect the stages 12, 14, 16 and 18, such that refrigerant can circulate therein. More precisely, refrigerant line 13 interconnects the compression stage 12 and the condensation stage 14, refrigerant line 15 interconnects the condensation stage 14 and the expansion stage 16, refrigerant line 17 interconnects the expansion stage 16 and the evaporation stage 18, and refrigerant line 19 interconnects the evaporation stage 18 and the compression stage 12.

[0016] As is well known in the art, the refrigerant enters the condensation stage 14 in a high-pressure gas stage, and exits as a liquid after heat has been released by heat exchange with another fluid, such as in rooftop condensers. In addition to a change of state, there is a temperature differential across the condensation stage 14. As previously mentioned, if the condensers of the condensation stage 14 operate at full capacity, and it is required to increase the amount of heat released at the condensation stage, the inlet temperature of the condensation stage can be increased to cause a greater temperature differential across the condensation stage, in order to increase the amount of energy released at the condensation stage. The temperature is increased at the inlet of the condensation stage 14 by increasing the compressor head pressure released by the compression stage 12.

[0017] In accordance with the present invention, a return line 20 is added to the refrigeration system 10 and extends between the refrigerant line 15 and the refrigerant line 13. The refrigerant return line 20 will direct a portion of the refrigerant exiting from the condensation stage 14 upstream to be re-injected into the condensation stage 14. In doing so, a portion of refrigerant will mix with refrigerant exiting from the compression stage 12 and pass through the condensation stage twice, whereby a greater amount of heat can be extracted therefrom. This double pass of refrigerant through the condensation stage 14 allows reduction of the inlet temperature with respect to a refrigeration system without a double pass. Therefore, for a constant inlet temperature, a double pass through the condensation stage 14 of a portion of the refrigerant will result in a greater amount of heat extracted from the refrigerant. The compressor head pressure is lowered because of this double pass cooling of the refrigerant, whereby the energy costs for compressing the refrigerant will also be reduced. Various valves must be provided in order to ensure that a predetermined adjustable quantity of refrigerant is reinjected upstream of the condensation stage 14, and a suitable valve configuration will be described hereinafter. It is noted, however, that a suitable valve configuration can substitute pumps. Accordingly, equipment costs and energy consumption are both lowered by the use of valves. Furthermore, suitable control means are also provided with the return line 20, so as to control the amount of energy released at the condensation stage 14.

[0018] An embodiment of the refrigeration system 20 is generally shown at 100 in FIG. 2. The refrigeration system 100 of FIG. 2 has a plurality of compressors 102, a condenser 104, and an evaporation stage 106. It is noted that the expansion valves and the evaporation coils of the evaporation stage 106 are not shown, but are typically known in the art. A compressor discharge line 110 receives a compressor discharge, namely high-pressure gas refrigerant, and directs the discharge to the condenser 104. The return feature described in FIG. 1 is initiated in FIG. 2 by a first-pass condenser line 112, which will direct a portion of the compressor discharge to the condenser 104. The first-pass condenser line 112 diverges from the discharge line 110 to reach the condenser 104. The first-pass condenser line 112 will thereafter merge with the second-pass condenser line 114 for the second-pass injection of already condensed refrigerant to the condenser 104, whereby, the condensed refrigerant will mix with high-pressure gas refrigerant of the discharge line 110, and thereby reduce the temperature of the refrigerant of the discharge line 110. The second-pass condenser line 114 is an extension of the discharge line 110, with a valve 116 therebetween. The valve 116 creates a pressure differential between the compressor discharge line 110 and the second-pass condenser line 114, such that an adjustable portion of the refrigerant is directed to the first-pass line 112. As mentioned previously, valve 116 is sufficient to ensure a desired flow of refrigerant through the condenser 104 without recourse to pumps. This results in a reduction in energy consumption, as well as represents a larger down cost for the refrigeration system 100. A portion of the refrigerant will be directed to the first-pass line 112, while the remainder of the refrigerant will go directly from the discharge line 110 to the second-pass condenser line 114.

[0019] A practical example is provided herewith to illustrate possible temperatures of operation of the refrigeration system 100. Reference letters A, B, C, D and E have been added to FIG. 2, and these reference letters are referred to in the table below to indicate where refrigerant pressure and temperature measurements have been taken. Note that these measurements are for an external temperature of 90°F, and that the refrigerant is, nonrestrictively, R-22. The condenser 104 is a rooftop condenser specified for total heat rejection of 450,000 Btu.
As a comparison, if refrigeration system 100 did not have a first-pass line 112, the pressure and temperature at A would be 240 psig and 280°F, to maximize the amount of heat rejected at the condensation stage. The double-pass configuration of the present invention enables to increase the amount of heat released by volume of refrigerant for a constant compressor head pressure.

The first pass in the condensation stage enables maximization of the total heat of rejection of the condenser 104 for lower refrigerant temperature and pressure, as illustrated above. The valve 116 creates the pressure differential between points A, B and point D.

Referring to FIG. 3, an alternative embodiment of the present invention is generally illustrated by refrigeration system 200, and generally has the same components and the same interrelations as the refrigeration system 100 of FIG. 2, whereby like components will bear the same reference numerals. Additional components, by which the refrigeration system 200 of FIG. 3 differs from the refrigeration system 100 of FIG. 2, are affixed with a prime (e.g., dedicated compressor 102'). The refrigeration system 200 has a plurality of compressors 102', as well as dedicated compressor 102'. The condenser 104 is provided downstream of the compressors 102 and 102'. Once more, the vaporization stage is generally shown at 106, but the expansion valves and the vaporization coils have been removed for clarity. In the refrigeration system 200, the compressor discharge line 110 collects the compressor discharge of the compressors 102. The compressor discharge line 110 is connected to the second-pass condenser line 114, and separated therefrom by the valve 116. The compressor 102' is connected to both the compressor discharge line 110 or to the condenser 104 via a first-pass condenser line 112'. Therefore, a valve 116' will direct a calculated quantity of refrigerant directly to the condenser 104 via the first-pass condenser line 112'. The refrigerant will exit from the condenser 104 to be directed thereafter to the second-pass condenser line 114, and will thereby cause the temperature of the refrigerant from the second-pass condenser line 114 to be reduced.

The compressor head pressure and temperature will be reduced for a same amount of heat released, because of the second pass. The compressors are thus used more efficiently, and thus the energy costs are reduced.

Once more, a practical example is provided to illustrate possible temperatures of operation of the refrigeration system 200. Reference letters have been added to FIG. 3, and these reference letters are referred to in the table below to indicate where refrigerant pressure and temperature measurements have been taken. The measurements are for an outdoor temperature of 90°F, the refrigerant is R-22, and the condenser 104, the same as in FIG. 2 (i.e., total heat of rejection of 450,000 Btu).

As a comparison, if refrigeration system 200 did not have a first-pass condenser line 112, the pressure and temperature at A would be 240 psig and 280°F, to obtain a temperature differential across the condenser 104 by which maximal heat of rejection will be achieved.

It is pointed out that the output of refrigerant of the condenser 104 is reduced as a portion of the refrigerant is recirculated in the condenser 14. Therefore, a liquid refrigerant reservoir 108 is preferred downstream of the condenser 104 (in FIGS. 2 and 3) to ensure that there is sufficient condensed refrigerant for the evaporation stage.

It is within the ambit of the present invention to cover any obvious modifications of the embodiments described herein, provided such modifications fall within the scope of the appended claims.

1. A condensing stage of a refrigeration system wherein a refrigerant goes through at least a compression stage, wherein said refrigerant is compressed to a high-pressure gas state to then reach said condensing stage through a high-pressure line, wherein said refrigerant in said high-pressure gas state is condensed at least partially to a high-pressure liquid state by releasing heat, to then reach an expansion stage, wherein said refrigerant in said high-pressure liquid state is expanded to a first low-pressure liquid state to then reach an evaporator stage, wherein said refrigerant in said first low-pressure liquid state is evaporated at least partially to a first low-pressure gas state by absorbing heat, to then return to said compression stage, said condensing stage comprising a refrigerant conveying line having an upstream end diverging from the high-pressure line to pass a portion of said refrigerant through said condensing stage, a downstream end of said refrigerant conveying line converging with the high-pressure line downstream of said upstream end of said refrigerant conveying line with respect to the high-pressure line to mix with refrigerant bypassing said refrigerant conveying line, prior to being fed to the condensing stage so as to increase the amount of heat released by volume of refrigerant in said condensing stage, and a valve in the high-pressure line between the upstream end and the downstream end of the refrigerant conveying line to control the amount of said portion of refrigerant.

2. A refrigeration system of the type wherein a refrigerant goes through at least a compression stage, wherein said refrigerant is compressed to a high-pressure gas state to then reach a condensing stage through a high-pressure line, wherein said refrigerant in said high-pressure gas state is condensed at least partially to a high-pressure liquid state by releasing heat, to then reach an expansion stage, wherein said refrigerant in said high-pressure liquid state is expanded to a first low-pressure liquid state to then reach an evaporator stage, wherein said refrigerant in said first low-pressure
liquid state is evaporated at least partially to a first low-pressure gas state by absorbing heat, to then return to said compression stage, the refrigeration system comprising means for directing a portion of said refrigerant from a downstream end of said condensing stage to an upstream end of said condensing stage, to mix said portion with refrigerant in said high-pressure gas state prior to being fed to the condensing stage so as to increase the amount of heat released by volume of refrigerant in said condensing stage.

3. The refrigeration system according to claim 2, wherein said condensing stage is fed said portion of refrigerant by a first heat release line and a remainder of said refrigerant by a second heat release line, both connected to said high-pressure line, said means for returning a portion of said refrigerant extending between a downstream end of said first heat release line and an upstream end of said second heat release line for conveying said portion of said refrigerant from said first heat release line to said second heat release line, said means comprising a valve on said high-pressure line between said first heat release line and said second heat release line to control the amount of said portion of refrigerant.

4. The refrigeration system according to claim 3, wherein said means comprises a refrigerant conveying line extending between a dedicated compressor of said compression stage to direct said portion of refrigerant to said condensing stage.

5. A method for increasing an amount of heat released by volume of refrigerant in a condensing stage of a refrigeration system of the type wherein said refrigerant goes through at least a compression stage, wherein said refrigerant is compressed to a high-pressure gas state to then reach said condensing stage, wherein said refrigerant in said high-pressure gas state is condensed at least partially to a high-pressure liquid state by releasing heat, to then reach an expansion stage, wherein said refrigerant in said high-pressure liquid state is expanded to a first low-pressure liquid state to then reach an evaporator stage, wherein said refrigerant in said first low-pressure liquid state is evaporated at least partially to a first low-pressure gas state by absorbing heat, to then return to said compression stage, said method comprising the steps of:

i) directing at least a portion of refrigerant to said condensing stage for a first pass; and

ii) redirecting said portion of refrigerant upstream of said condensing stage to mix said portion of refrigerant with said refrigerant in said high-pressure gas state.

6. The method according to claim 5, comprising a step, prior to step i), of providing a valve between said compression stage and said condensing stage to control the amount of said portion of refrigerant.

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