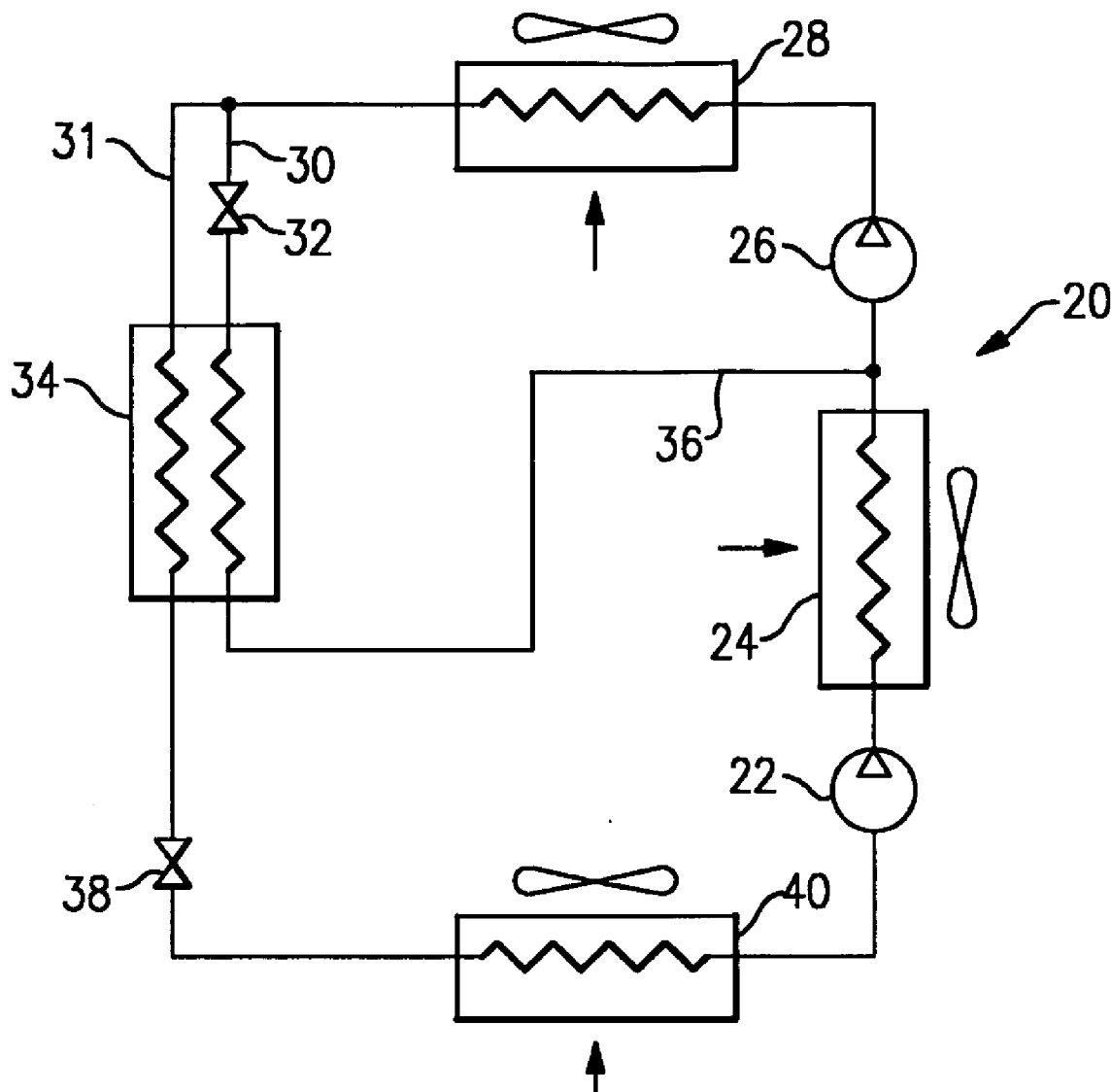


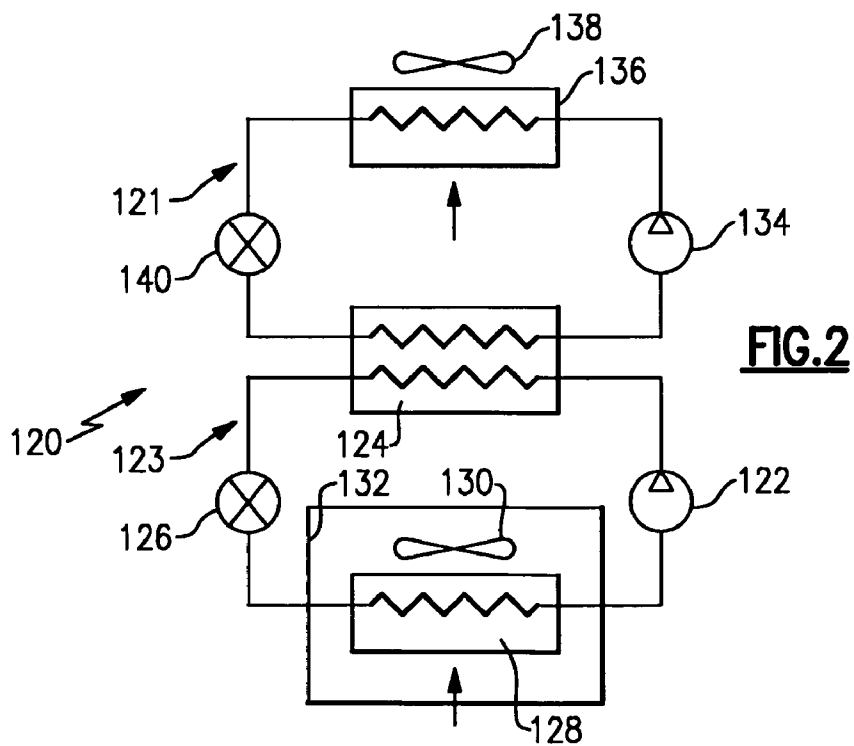
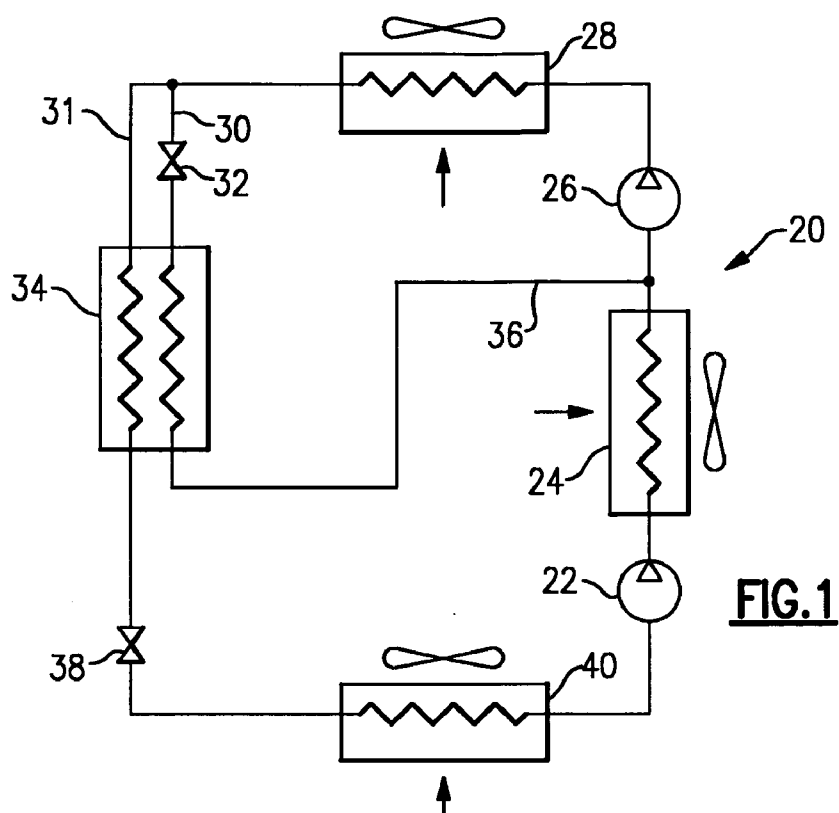


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(US); **Michael F. Taras**,
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(2), (4) Date: **Feb. 9, 2010**(57) **ABSTRACT**

Multi-stage refrigerant systems operate with a lower stage compressor of a first type and a higher stage compressor of a second type. In one embodiment, the lower stage compressor type is selected to have the most beneficial characteristics at lower pressure operation, while the higher pressure stage compressor type is selected to have the most beneficial characteristics at higher pressure operation.





MULTI-STAGE REFRIGERANT SYSTEM WITH DIFFERENT COMPRESSOR TYPES

BACKGROUND OF THE INVENTION

[0001] This application relates to a multi-stage refrigerant system, wherein a lower compression stage and a higher compression stage are provided with different compressor types.

[0002] In known refrigerant systems, a refrigerant is circulated from a compressor, to a heat rejection heat exchanger, known as a condenser for subcritical systems and as gas cooler for transcritical systems, then through an expansion device, and to a heat accepting heat exchanger, known as an evaporator. Many enhancement options and design features can be provided to improve operation of these basic refrigerant systems.

[0003] One enhancement that is known in the art of air conditioning and refrigeration is the use of multi-stage refrigerant system design concepts. In a multi-stage refrigerant system, a lower stage operates at a lower pressure and a higher stage operates at a higher pressure. Recently, R774 refrigerant, commonly known as CO₂, has been identified as a promising natural refrigerant that has zero ozone depletion potential, and extremely low global warming potential. Thus, CO₂ is becoming more widely utilized as a refrigerant of choice to replace conventional refrigerants. However, refrigerant systems utilizing CO₂ as a refrigerant must operate at a higher pressure, and quite often at a higher discharge temperature. Also, the CO₂ refrigerant systems are often not as efficient as refrigerant systems employing conventional refrigerants. To alleviate these problems, multi-stage refrigerant system schematics, rather than single stage refrigerant system schematics, are more likely to be implemented for applications utilizing an environmentally friendly natural CO₂ refrigerant.

[0004] A multi-stage refrigerant system can be provided by having two compressors operating in series. A lower stage compressor compresses the refrigerant to an intermediate pressure, and that refrigerant then passes to a higher stage compressor.

[0005] In another type of multi-stage refrigerant system, or so-called cascade refrigerant systems, the lower and higher stages are associated with entirely separate circuits. In a lower pressure closed-loop circuit, the lower stage compressor discharges refrigerant into a refrigerant-to-refrigerant heat exchanger, which plays a role of a heat rejection heat exchanger for this circuit, passes that refrigerant through an expansion device and heat accepting heat exchanger connected in series and then returns the refrigerant to the lower stage compressor. In a higher pressure closed-loop circuit, the higher stage compressor receives refrigerant from the same refrigerant-to-refrigerant heat exchanger, which is a heat accepting heat exchanger for this circuit, discharges that refrigerant to a heat rejection heat exchanger (either a condenser or a gas cooler) and then passes the refrigerant through an expansion device, downstream of which the refrigerant is returned to the refrigerant-to-refrigerant heat exchanger. Thus, in cascade refrigerant systems, the heat is transferred from the lower stage to the higher stage in the refrigerant-to-refrigerant heat exchanger, which is typically configured as a counterflow heat exchanger.

[0006] Some compressor types, which are suitable for low pressure operation, cannot reliably operate at a high pressure. One such compressor is a scroll compressor. A conventional scroll compressor may not operate reliably and/or efficiently

above about 700 psia. The use of CO₂ refrigerant would normally call for operation at discharge pressures about 2000 psia. Thus, this makes conventional scroll compressor designs not applicable for many CO₂ applications. Further, different compressor types may be suitable for different pressure ratios or pressure difference ranges, depending on a particular compressor type design.

[0007] To date, refrigerant systems which utilize two stages have employed the same type compressors for both stages. In the past, this was acceptable for many compressor types, such as scroll compressors, screw compressors, rotary compressors, reciprocating compressors and the like, while also using conventional relatively low pressure refrigerants such as R134a, R22, R410A, R404A and the like. However, the high pressure refrigerants, such as CO₂, precluded the use of many compressor types, which, at least to date, have experienced difficulty in operating as a higher pressure stage compressor.

SUMMARY OF THE INVENTION

[0008] In the disclosed embodiment of this invention, a refrigerant system is provided with multiple sequential stages (and at least two sequential stages). At least one compressor associated with one of the multiple stages, is a distinct compressor type as compared to the other stages. In this way, a compressor which is best suited for the lower pressure stage can be used for the lower pressure stage, while a compressor that is best suited for a higher pressure stage can be utilized for the higher pressure stage. The multi-stage refrigerant system can utilize multiple compressors compressing the refrigerant in series, or can utilize cascaded refrigerant circuits.

[0009] These and other features of the present invention can be best understood from the following specification and drawings, the following of which is a brief description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. 1 shows a first schematic of this invention.

[0011] FIG. 2 shows the second schematic of this invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0012] FIG. 1 shows a refrigerant system 20 incorporating a lower stage compressor 22 which delivers a compressed refrigerant to an optional intercooler 24. From the intercooler 24 the refrigerant moves to a higher stage compressor 26, and then to a heat rejection heat exchanger 28. The refrigerant system 20 may also be equipped with an optional, to this invention, economizer cycle. In this case, a portion of refrigerant may be tapped to a tap refrigerant line 30 downstream of the heat rejection heat exchanger 28, and passed through an economizer expansion device 32. The tapped partially expanded refrigerant passes through an economizer heat exchanger 34 at which it further cools the main refrigerant flow in a liquid refrigerant line 31. The tapped partially expanded refrigerant is returned through a return refrigerant line 36 to an intermediate compression point between the two compression stages 22 and 26. It has to be noted that the return point of the refrigerant line 36 is preferably located downstream of the intercooler 24. The refrigerant circuit elements (or components) 30, 32, 34, and 36 is known as an economizer circuit. While the tapped refrigerant flow is shown passing in the same direction through the economizer heat exchanger 34 as the main refrigerant flow, in practice, it is often preferable to pass the two refrigerant flows in a counterflow configura-

tion. However, for illustration simplicity the refrigerant streams are shown flowing in the same direction. Also, it should be understood that, in the context of this invention, a flash tank can be considered as a subset of an economizer heat exchanger. Further, various economizer cycle configurations are feasible and within the scope of the invention.

[0013] Downstream of the economizer heat exchanger **34** the refrigerant passes through a main expansion device **38**, and then a heat accepting heat exchanger **40**.

[0014] In a disclosed feature of this application, the lower stage compressor **22** is a distinct compressor type from the higher stage compressor type **26**. In one embodiment, the lower stage compressor **22** may be a scroll compressor, which has beneficial characteristics at lower pressure operation. The higher stage compressor **26** may be selected to have beneficial characteristics at higher pressure operation. As an example, the higher stage compressor **26** may be a reciprocating compressor. Further, the distinct compressor types may be selected based on a pressure ratio, pressure difference, discharge temperature, suction temperature or a combination of these parameters.

[0015] By employing this arrangement, existing scroll compressors, for instance, can be utilized in applications to which they are best suited, while not being utilized, for instance, in the higher pressure stages where they are perhaps provide less reliable or/and efficient operation.

[0016] While only two compressor types are disclosed, the two distinct compressor types **22** and **26** can be of any other compressor types such as screw compressors, rotary compressors, etc. Further, more than two sequential compression stages may be provided with the refrigerant system **20**, if desired.

[0017] FIG. 2 shows a refrigerant system **120** incorporating two cascaded closed-loop refrigerant circuits **121** and **123**. A lower stage refrigerant circuit **123** includes a lower stage compressor **122** delivering a compressed refrigerant into a refrigerant-to-refrigerant heat exchanger **124** that is a heat rejection heat exchanger for the refrigerant circuit **123**. The refrigerant-to-refrigerant heat exchanger **124** is preferably positioned outside of an environment **132** to be conditioned. Refrigerant passes from the heat exchanger **124** through an expansion device **126**, and to a heat accepting heat exchanger or evaporator **128**. As known, a fan **130** may be associated with and blow air over external surfaces of the heat accepting heat exchanger **128** to deliver that conditioned air into the climate-controlled environment **132**. The lower stage refrigerant circuit **123** would normally be charged with a refrigerant that would operate in a subcritical region. One such environmentally friendly natural refrigerant that can be used for the circuit **123** would be the CO₂ refrigerant that, while in the lower cascaded circuit, would still be operating in the subcritical region. If the CO₂ refrigerant is used in the upper cascaded circuit, it is likely to operate in a transcritical region. In the upper stage refrigerant circuit **121**, an upper stage compressor **134** compresses a refrigerant and delivers it to a heat rejection heat exchanger **136**. A fan **138** may be associated with and blow air over the external surfaces of the heat rejection heat exchanger **136**. Refrigerant passes from the heat rejection heat exchanger **136** downstream to an expansion device **140**, and then back through the refrigerant-to-refrigerant heat exchanger **124**, which is a heat accepting heat exchanger for the upper refrigerant circuit **121**, to the upper stage compressor **134**. It has to be noted that if the upper refrigerant circuit **121** is operating in a transcritical cycle, the

heat rejection heat exchanger **136** is a gas cooler. On the other hand, if the upper refrigerant circuit **121** is operating in a subcritical cycle, the heat rejection heat exchanger **136** is a condenser. In some applications, the upper refrigerant circuit **121** may be operating for part of the time in a transcritical cycle and for part of the time in a subcritical cycle.

[0018] Again, the compressors **122** and **134** are selected to be of distinct types. In one disclosed embodiment, the lower stage compressor **122** is a scroll compressor while the higher stage compressor **134** may be a reciprocating compressor. Once again, as has been explained above, the distinct compressor types may be selected based on the suction pressure, discharge pressure, equilibrium pressure, pressure ratio, pressure difference, discharge temperature, suction temperature or a combination of these parameters.

[0019] It also should be understood that the number of the closed-loop cascaded refrigerant circuits may be more than two and the number of distinct compressor types may be more than two as desired.

[0020] The embodiments of FIGS. 1 and 2 are particularly well suited for refrigerant systems utilizing CO₂ as a refrigerant. It should be understood that other means of heat exchange between the refrigerant and conditioned environment as well as the refrigerant and heat rejection environment may be employed, including, for example, a delivery of water or brine by pumps. Also, as mentioned above, it should be understood that while the FIGS. 1 and 2 show the two-stage refrigerant systems, more than two stages can be employed, with at least one compressor type being different from the rest.

[0021] 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.

[0022] 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.

[0023] While embodiments of this invention have been disclosed, a worker of ordinary skill in this art would recognize that certain modifications would come within the scope of this invention. For that reason, the following claims should be studied to determine the true scope and content of this invention.

We claim:

1. A multi-stage refrigerant system comprising:
 - at least two compressors, with a lower stage compressor and a higher stage compressor;
 - a heat rejection heat exchanger for receiving refrigerant from said higher stage compressor, and a heat accepting heat exchanger for delivering refrigerant to a lower stage compressor; and
 - said higher and lower stage compressors being different compressor types.
2. The refrigerant system as set forth in claim 1, wherein said lower stage compressor and said higher stage compressor are positioned to compress refrigerant in a serial fashion.
3. The refrigerant system as set forth in claim 2, wherein an intercooler is positioned between said lower stage compressor and said higher stage compressor.
4. The refrigerant system as set forth in claim 2, wherein an economizer circuit is provided within the refrigerant system

and returns a tapped refrigerant to an intermediate compression point between said lower stage compressor and said higher stage compressor.

5. The refrigerant system as set forth in claim 1, wherein the multi-stage refrigerant system includes two to four stages.

6. The refrigerant system as set forth in claim 1, wherein the multi-stage refrigerant system operates in a transcritical cycle for at least a portion of the time.

7. The refrigerant system as set forth in claim 1, wherein at least one of the multiple stages operates with the CO₂ refrigerant.

8. The refrigerant system as set forth in claim 1, wherein said higher stage compressor and said lower stage compressor are each part of their own closed-loop refrigerant circuit, and wherein refrigerant compressed by said lower stage compressor is delivered into a refrigerant-to-refrigerant heat

exchanger, and refrigerant received by said higher stage compressor is delivered from the same refrigerant-to-refrigerant heat exchanger.

9. The refrigerant system as set forth in claim 1, wherein said lower stage compressor is a scroll compressor.

10. The refrigerant system as set forth in claim 9, wherein said higher stage compressor is not a scroll compressor.

11. The refrigerant system as set forth in claim 1, wherein said higher stage compressor is a reciprocating compressor.

12. The refrigerant system as set forth in claim 11, wherein said lower stage compressor is not a reciprocating compressor.

13. The refrigerant system as set forth in claim 1, wherein said different compressor types are selected based on at least one of suction pressure, discharge pressure, equilibrium pressure, pressure ratio, pressure difference, discharge temperature, suction temperature.

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