A dual evaporator refrigerator appliance is disclosed. The appliance includes a first evaporator, a second evaporator, and at least one refrigerant stream combining device. Refrigerant flow control techniques are provided whereby a compressor in the refrigerator appliance that receives a resulting refrigerant stream is required to do less work to raise the pressure of the stream, and thus the refrigerator appliance is more energy efficient.
FIG. 1
FIG. 7

Stream Pressure: $P \approx 15$ psi

From FZ Evaporator 612

Stream Pressure: $P = 50-100$ psi

From Phase Separator (Liquid) 608

From Phase Separator (Vapor) 608

To FF Evaporator 614

Stream Pressure: $P \approx 15$ psi : $< P \leq 30$ psi

Stream Pressure: $P = 50-100$ psi
FIG. 8
DUAL EVAPORATOR REFRIGERATION
SYSTEM

BACKGROUND OF THE INVENTION

[0001] The subject matter disclosed herein relates to dual evaporator refrigerator appliances, and more particularly to increasing energy efficiency in such a dual evaporator refrigerator appliance.

[0002] Many refrigerator appliances are based on a vapor-compression refrigeration technique. In such a refrigeration technique, a refrigerant serves as the medium that absorbs and removes heat from the space to be cooled, and transfers the heat elsewhere for rejection.

[0003] Some refrigerator appliances are designed to have two separate evaporators, for example, one serving as an evaporator in a freezer compartment of the refrigerator (i.e., a freezer evaporator) and the other serving as an evaporator in a fresh food compartment of the refrigerator (i.e., a fresh food evaporator). The evaporator is the part of the refrigeration system through which the refrigerant passes to absorb and remove the heat in the compartment being cooled (e.g., freezer compartment or fresh food compartment).

[0004] Dual evaporator refrigeration systems have certain advantages over single evaporator refrigeration systems. For example, many dual evaporator systems have separate refrigeration cycles for the freezer compartment and the fresh food compartment. Most dual evaporator systems have isolated airflow systems and thus the airflow in the refrigerator does not circulate between both compartments as it does in a single evaporator refrigeration system. Thus, by having an isolated airflow system in a dual evaporator system, odors that come from food stored in the fresh food compartment do not carry into the freezer compartment and then settle in ice cubes made in the freezer compartment causing unpleasant tastes when consuming the ice cubes.

[0005] However, dual evaporator refrigeration systems typically operate the freezer evaporator at a refrigerant pressure that is lower than that of the fresh food evaporator. This is because the fresh food compartment is maintained at a higher temperature than the freezer compartment. Thus, the compressor that receives the refrigerant exiting the freezer evaporator must do more work to raise the refrigerant pressure before sending it to the condenser, as compared with the higher pressure refrigerant exiting the fresh food evaporator.

BRIEF DESCRIPTION OF THE INVENTION

[0006] As described herein, the exemplary embodiments of the present invention overcome one or more disadvantages known in the art.

[0007] One aspect of the present invention relates to a dual evaporator refrigerator appliance comprising a first evaporator, a second evaporator, a phase separator and a refrigerant stream combining device. The phase separator is coupled to an input of the first evaporator and an input of the second evaporator, wherein the phase separator provides a refrigerant stream in a vapor phase part and a liquid phase part to the input of the first evaporator and a refrigerant stream in a liquid phase to the input of the second evaporator. The refrigerant stream combining device is coupled to an output of the first evaporator and an output of the second evaporator, wherein the refrigerant stream combining device receives a first refrigerant stream having a first pressure from the output of the first evaporator and a second refrigerant stream having a second pressure from the output of the second evaporator, and generates an output refrigerant stream having a pressure greater than the second pressure.

[0008] Another aspect of the present invention relates to a dual evaporator refrigerator appliance comprising a first evaporator, a second evaporator and a refrigerant stream combining device. The refrigerant stream combining device is coupled between an output of the second evaporator and an input of the first evaporator, wherein the refrigerant stream combining device receives a first refrigerant stream having a first pressure and receives a second refrigerant stream having a second pressure from the output of the second evaporator, and generates an output refrigerant stream having a pressure greater than the second pressure, the output refrigerant stream being provided to the input of the first evaporator.

[0009] Yet another aspect of the present invention relates to a dual evaporator refrigerator appliance comprising a first evaporator, a second evaporator, a phase separator, a first refrigerant stream combining device and a second refrigerant stream combining device. One output of the phase separator is coupled to one input of the first refrigerant stream combining device and another output of the phase separator is coupled to one input of the second refrigerant stream combining device, and an output of the second evaporator is coupled to another input of the second refrigerant stream combining device while an output of the second refrigerant stream combining device is coupled to another input of the first refrigerant stream combining device, and an output of the first refrigerant stream combining device is coupled to an input of the first evaporator. The phase separator provides a refrigerant stream in one phase and a refrigerant stream in another phase that are respectively used by the first and second refrigerant stream combining devices to generate an output refrigerant stream having a pressure that is greater than a pressure of a refrigerant stream output by the second evaporator, the output refrigerant stream being input to the first evaporator. It is to be appreciated that the term “device,” as used in this particular aspect of the invention, comprises an embodiment where “the first refrigerant stream combining device” and “the second refrigerant stream combining device” are realized in physically-separate devices, and an embodiment where “the first refrigerant stream combining device” and “the second refrigerant stream combining device” are realized in a single physical device.

[0010] A further aspect of the present invention relates to a dual evaporator refrigerator appliance comprising a first evaporator, a second evaporator, and a phase separator and a refrigerant stream combining device. The phase separator has an input coupled to an output of the first evaporator. The phase separator separates a refrigerant stream into a predominantly first phase part and a predominantly second phase part. The refrigerant stream combining device is coupled to an output of the second evaporator and an output of the phase separator. The refrigerant stream combining device receives a first refrigerant stream having a first pressure from an output of the phase separator and a second refrigerant stream having a second pressure from an output of the second evaporator, and generates an output refrigerant stream having a pressure greater than the second pressure.

[0011] Advantageously, illustrative techniques of the present invention provide refrigerant flow control whereby a compressor that receives a resulting refrigerant stream is required to do less work to raise the pressure of the stream, and thus the refrigerator appliance is more energy efficient.
These and other aspects and advantages of the present invention will become apparent from the following detailed description considered in conjunction with the accompanying drawings. It is to be understood, however, that the drawings are designed solely for purposes of illustration and not as a definition of the limits of the invention, for which reference should be made to the appended claims. Moreover, the drawings are not necessarily drawn to scale and, unless otherwise indicated, they are merely intended to conceptually illustrate the structures and procedures described herein.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagram of a refrigerator, in accordance with one embodiment of the invention;
FIG. 2 is a diagram of a dual evaporator refrigeration system, in accordance with one embodiment of the invention;
FIG. 3 is a diagram illustrating refrigerant flow associated with a refrigerant stream combining device in the dual evaporator refrigeration system of FIG. 2;
FIG. 4 is a diagram of a dual evaporator refrigeration system, in accordance with another embodiment of the invention;
FIG. 5 is a diagram illustrating refrigerant flow associated with a refrigerant stream combining device in the dual evaporator refrigeration system of FIG. 4;
FIG. 6 is a diagram of a dual evaporator refrigeration system, in accordance with yet another embodiment of the invention;
FIG. 7 is a diagram illustrating refrigerant flow associated with refrigerant stream combining devices in the dual evaporator refrigeration system of FIG. 6;
FIG. 8 is a diagram of a dual evaporator refrigeration system, in accordance with a further embodiment of the invention.

DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENTS OF THE INVENTION

One or more of the embodiments of the invention will be described below in the context of a refrigerator appliance such as a household refrigerator. However, it is to be understood that methods and apparatus of the invention are not intended to be limited to use in household refrigerators. Rather, methods and apparatus of the invention may be applied to and deployed in any other suitable environments in which it would be desirable to improve energy efficiency in the case of a dual evaporator system.

FIG. 1 illustrates an exemplary refrigeration appliance 100 within which embodiments of the invention may be implemented. As is typical, a refrigerator has a freezer compartment 102 and a fresh food compartment 104. The fresh food compartment typically maintains foods and products stored therein at temperatures at or below about 40 degrees Fahrenheit in order to preserve the items therein, and the freezer compartment typically maintains foods and products at temperatures below about 32 degrees Fahrenheit in order to freeze the items therein.

As mentioned above, in a dual evaporator system, one evaporator is used to cool the freezer compartment 102 and another evaporator is used to cool the fresh food compartment 104.

While the exemplary refrigerator 100 in FIG. 1 illustrates the freezer compartment 102 and the fresh food compartment 104 in a side-by-side configuration, it is to be understood that other configurations are known, such as top freezer configurations where the freezer compartment 102 is situated on top of the fresh food compartment 104, and bottom freezer configurations where the freezer compartment 102 is situated below the fresh food compartment 104. Also, viewing the refrigerator 100 from the front, the freezer compartment 102 may be located to the right of the fresh food compartment 104, as opposed to being located to the left as shown in FIG. 1.

It is to be appreciated that embodiments of the invention may be implemented in the refrigerator 100. However, methods and apparatus of the invention are not intended to be limited to implementation in a refrigerator such as the one depicted in FIG. 1. That is, the inventive methods and apparatus may be implemented in other household refrigerator appliances, as well as non-household (e.g., commercial) refrigerator appliances. Furthermore, such inventive methods and apparatus may be generally implemented in any appropriate refrigerator system.

As mentioned above, dual evaporator refrigeration systems typically operate the freezer evaporator at a refrigerant pressure that is lower than that of the fresh food evaporator. Again, this is because the fresh food compartment need not maintain the same lower temperature as the freezer because it is not the intention to freeze the food in the fresh food compartment but merely to preserve its freshness. Thus, because of this lower refrigerant pressure, the compressor that receives the refrigerant exiting the freezer evaporator must do more work, i.e., expend more energy, to raise the refrigerant pressure before sending it to the next stage of the refrigeration cycle.

To overcome this and other problems with existing approaches, principles of the invention provide an improved refrigeration system that captures more of the energy savings available from the use of a dual evaporator system. That is, principles of the invention provide for cooling each compartment (freezer and fresh food) separately and then combining the refrigerant flow streams using a refrigerant stream combining device, such as a Venturi jet pump.

Advantageously, as will be explained in the context of the various illustrative embodiments, the use of a refrigerant stream combining device, such as a Venturi jet pump, allows the compressor to operate more efficiently because the refrigerant entering the compressor is at a higher pressure than would otherwise be the case with existing dual evaporator refrigeration systems. Further, it is realized that new government regulations and consumer demand strongly encourage the development of low energy use appliances. The refrigeration system of the invention reduces energy use in a very cost effective manner, while providing all the benefits expected from a dual evaporator system. These benefits include, but are not limited to, better food preservation, internal condensation prevention, and elimination of odor transfer between compartments.

FIG. 2 is a diagram of a dual evaporator refrigeration system, in accordance with one embodiment of the invention. It is to be understood that the dual evaporator refrigeration system 200 of FIG. 2 may be implemented in the refrigerator 100 in FIG. 1. That is, one of the two evaporators is used in the freezer compartment 102 and the other one is used in the fresh food compartment 104.
The refrigeration system 200 shown in FIG. 2 uses a circulating refrigerant as the medium which absorbs and removes heat from the compartments to be cooled and subsequently expels the heat elsewhere. A refrigerant is a compound used in a heat cycle that reversibly undergoes a phase change from a gas to a liquid. Examples of refrigerants used in refrigerator appliances include but are not limited to the R-12, R-22, R-134a and R-600a. While certain older refrigerants are being phased out and replaced by environmentally-friendly compounds, it is to be understood that the principles of the invention are not limited to any particular refrigerant.

As shown in FIG. 2, circulating refrigerant enters a compressor 202 in a thermodynamic state known as a “superheated vapor” and is compressed to a higher pressure in the compressor 202, resulting in a higher temperature as well. The hot, compressed vapor exiting the compressor 202 is still in a thermodynamic state known as a “superheated vapor,” but it is now at a temperature and pressure at which it can be condensed with typically available cooling water or cooling air. Thus, the hot vapor is routed through a condenser 204 where it is cooled and condensed into a liquid by flowing through a coil or tubes with cool water or cool air flowing across the coil or tubes of the condenser. The cool air may typically be air in the room in which the refrigeration operates. It is to be understood that the condenser 204 is where the circulating refrigerant rejects heat from the system and the rejected heat is carried away by either the water or the air (dependent on which one the condenser uses).

The condensed liquid refrigerant, in a thermodynamic state known as a “saturated liquid,” is next routed to a first reducer 206. One form of a reducer is a capillary tube. The refrigerant undergoes an abrupt reduction in pressure in the first reducer 206. That pressure reduction results in the evaporation of a part of the liquid refrigerant. The lower pressure lowers the temperature of the liquid and vapor refrigerant mixture to where it is colder than the temperature of the enclosed compartment to be refrigerated.

From the first reducer 206, the liquid and vapor refrigerant mixture goes to a phase separator 208. In phase separator 208, the refrigerant mixture is separated into its two phases, i.e., liquid and vapor. The predominantly liquid part of the refrigerant goes through a second reducer 210 (e.g., capillary tube). The refrigerant output from the second reducer 210 then goes to a freezer evaporator (FZ) 212 (i.e., evaporator in the freezer compartment of the refrigerator). On the other hand, the predominantly vapor part of the refrigerant output from the phase separator 208 goes to the fresh food evaporator (FF) 214 (i.e., evaporator in the fresh food compartment of the refrigerator). Thus, it is to be understood that refrigerant passes substantially simultaneously to the two evaporators 212 and 214 in the system.

In each compartment to be cooled by an evaporator, a fan (213 in FZ and 215 in FF) circulates the warm air in the enclosed compartment across the coil or tubes of the evaporator carrying the cold refrigerant liquid and vapor mixture. The warm air evaporates the liquid part of the cold refrigerant mixture. At the same time, the circulating air is cooled and thus lowers the temperature of the enclosed compartment to a desired temperature. The temperature is monitored by a temperature sensor (not shown) and can thus be controlled at a desired level. It is to be understood that the evaporator is where the circulating refrigerant absorbs and removes heat which is subsequently rejected in the condenser and transferred elsewhere by the water or air used in the condenser.

To complete the refrigeration cycle, the refrigerant vapor exits each evaporator, as a “saturated vapor,” and is routed back to the compressor 202. The saturated vapor may become superheated while exchanging heat with the capillary tube in the suction line capillary tube heat exchanger. The cycle is then repeated.

However, in accordance with principles of the invention, the refrigerant flow streams exiting from each evaporator (FZ 212 and FF 214) are combined in a refrigerant stream combining device 216 before being routed back to the compressor 202. In one illustrative embodiment, such a refrigerant stream combining device is a Venturi jet pump. Recall, as mentioned above, that use of a refrigerant stream combining device, such as a Venturi jet pump, allows the compressor 202 to operate more efficiently because the refrigerant entering the compressor (as output by the refrigerant stream combining device 216) is at a higher pressure than would otherwise be the case if the streams exiting the evaporators were simply fed together into a single input to the compressor (without the refrigerant stream combining device). This is because the pressure of the refrigerant stream exiting the freezer evaporator 212 (about 15 pounds-force per square inch or psi) is lower than the pressure of the refrigerant stream exiting the fresh food evaporator 214 (about 30 psi) due to the fact that the freezer compartment is maintained at a lower temperature than the fresh food evaporator. As such, if the streams were merely merged without the use of the refrigerant stream combining device 216, then the resulting pressure of the refrigerant entering the compressor would be that of the lower pressure stream, i.e., the 15 psi freezer stream. However, as will be seen, the stream output by the refrigerant stream combining device 216 is at a pressure that is greater than the pressure of the refrigerant stream exiting the freezer evaporator 212 and less than the pressure of the refrigerant stream exiting the fresh food evaporator 214. That is, in the above example, the pressure P of the stream output by the refrigerant stream combining device 216 would be in the following range: about 15 psi to about 30 psi.

FIG. 3 is a diagram illustrating refrigerant flow associated with the refrigerant stream combining device 216 in the dual evaporator refrigeration system of FIG. 2. In one illustrative embodiment, it is to be appreciated that the nozzle diameter (ND) of device 216 is preferably less than about 0.060 inches. The minimum diffuser diameter (DD) is preferably less than about 0.120 inches and greater than the nozzle diameter. The converging and diverging sections of the diffuser are smooth and designed to minimize flow losses and maximize efficiency. As shown, the refrigerant stream exiting the fresh food evaporator 214 is provided to a first input 302 (nozzle) of the refrigerant stream combining device 216. This stream is called the “motive fluid.” Further, the refrigerant stream exiting the freezer evaporator 212 is provided to a second input 304 (diffuser) of the refrigerant stream combining device 216. This stream is called the “suction fluid.” The motive fluid is therefore at a higher pressure than the suction fluid.

In operation, the refrigerant stream combining device 216 accelerates the refrigerant stream that is at the higher pressure (fresh food stream) to reduce its static pressure beneath that of the freezer refrigerant stream. This is accomplished by converting a portion of the static pressure associated with the fresh food stream into a dynamic pressure, thus allowing the fresh food stream and the freezer stream to
mix and then expand at an output 306 of the refrigerant stream combining device 216. It is to be understood that while a portion of the static pressure of the fresh food stream is converted to dynamic pressure, total pressure is conserved in a lossless, ideal Venturi. In practice, there is a reduction in pressure due to losses. This pressure conversion, mixing and expansion results in the refrigerant stream output by the combining device being at a pressure that is higher than the pressure of the suction fluid (freezer evaporator) stream, preferably approaching the pressure of the motive fluid (fresh food evaporator) stream. It is to be understood that, as used illustratively herein, “total pressure” is the sum of “static pressure” and “dynamic pressure.” Static pressure is a property of a fluid, and can be calculated by measuring the force that a still liquid or gas exerts on a container per unit area. Dynamic pressure is a term that represents the kinetic energy of fluid. It is a function of the fluid velocity and density.

Another way to view the operation of the refrigerant stream combining device is that the motive stream is accelerated to a high velocity in the nozzle and transfers some energy to the low velocity stream by entraining the low velocity stream. The two streams are mixed and then slowed in the diffusing section to change the dynamic pressure to static pressure.

By way of example, assuming the pressure of the fresh food stream is about 30 psi and the pressure of the freezer stream is about 15 psi, the output of the refrigerant stream combining device 216 is at a pressure greater than 15 psi and less than 30 psi, e.g., about 19 psi with appropriate energy conversion in the device. Thus, the result of the refrigerant stream combining device is that the device yields an output stream having a pressure that is higher than the pressure of the lower of the two input streams.

Furthermore, as is advantageously realized in the embodiment of FIGS. 2 and 3, the refrigerant that goes to the freezer evaporator is more liquid and can therefore absorb more heat. Thus, the mass flow going to the fresh food evaporator is greater than that going to the freezer evaporator. As a result, because a larger mass flow, high pressure stream is being input to the refrigerant stream combining device, a higher pressure stream is output from the device. The compressor therefore does less work and the refrigerant is, in turn, more energy efficient. Still further, it is to be appreciated that the phase separator advantageously increases the percentage of high pressure refrigerant that serves as motive gas (vapor) in the refrigerant stream combining device 216 and decreases the amount of suction or low pressure gas entering the refrigerant stream combining device 216. This improved ratio of high pressure versus low pressure vapor increases the outlet pressure and the system efficiency.

FIG. 4 is a diagram of a dual evaporator refrigeration system, in accordance with another embodiment of the invention. It is to be understood that the dual evaporator refrigeration system 400 of FIG. 4 may be implemented in the refrigerator 100 of FIG. 1. That is, one of the two evaporators is used in the freezer compartment 102 and the other one is used in the fresh food compartment 104.

It is to be understood that the components of the refrigeration system 400 shown in FIG. 4 are generally similar in function to the components of the refrigeration system 200 shown in FIG. 2, with the exception of the features to be described herein below. As such, the reference numerals of components have simply been incremented by 200, i.e., compressor 402 is generally similar to compressor 202, condenser 404 is generally similar to condenser 204, first and second reducers 406 and 410 are generally similar to first and second reducers 206 and 210, freezer evaporator 412, fan 413, fresh food evaporator 414 and fan 415 are generally similar to freezer evaporator 212, fan 213, fresh food evaporator 214 and fan 215. One will note that a main difference between the embodiment of FIG. 2 and the embodiment of FIG. 4 is the placement of the refrigerant stream combining device 416 and its operation in the refrigeration system, and the lack of inclusion of a phase separator in the embodiment of FIG. 4.

As shown, both the fresh food and freezer evaporators are fed substantially simultaneously. Because the stream output from the condenser 404 is split, at point 401 in FIG. 4, smaller evaporators can be used as compared to existing two evaporator systems. One refrigerant stream then goes to the first reducer 406 and the second refrigerant stream goes to the second reducer 410, where the pressure reduction results in evaporation of a part of the liquid refrigerant in each stream.

The output of the second reducer 410 is provided to the freezer evaporator 412. The refrigerant passing through the freezer evaporator absorbs the heat in the freezer compartment, as explained above, and exits the freezer evaporator 412.

In accordance with this illustrative embodiment of the invention, the refrigerant stream exiting the freezer evaporator 412 and the refrigerant stream exiting the first reducer 406 are combined in the refrigerant stream combining device 416. The pressure of the refrigerant exiting the first reducer, which is a higher pressure relative to the freezer evaporator output, is thus used to raise the pressure of the refrigerant leaving the freezer evaporator, which is at a lower pressure relative to the first reducer output. The combined flows are then used to cool the fresh food evaporator 414. The enthalpy change across the fresh food evaporator is reduced because the refrigerant entering from the freezer evaporator is vapor, but the mass flow is increased. The refrigerant exiting the fresh food evaporator 414 is then routed to the compressor 402 such that the refrigeration cycle is repeated.

FIG. 5 is a diagram illustrating refrigerant flow associated with the refrigerant stream combining device 416 in the dual evaporator refrigeration system of FIG. 4. In an illustrative embodiment, the device 416 may have the same or similar dimensions as described above in the context of FIG. 3. As shown, the refrigerant stream exiting the first reducer 406 is provided to a first input 502 of the refrigerant stream combining device 416. This stream is called the “motive fluid.” Further, the refrigerant stream exiting the freezer evaporator 412 is provided to a second input 504 of the refrigerant stream combining device 416. This stream is called the “suction fluid.” The motive fluid is therefore at a higher pressure than the suction fluid.

In operation, the refrigerant stream combining device 416 accelerates the refrigerant stream from the first reducer, which has a low static pressure, thus pulling in the lower pressure refrigerant from the freezer evaporator. Expanding the flow reduces the dynamic pressure and increases the static pressure. The refrigerant stream output by the combining device at output 506 is thus at a pressure that is higher than the pressure of the suction fluid (freezer evaporator) stream, preferably approaching the pressure of the motive fluid (first reducer) stream.

By way of example, assuming the pressure of the first reducer stream is about 50 psi (e.g., can range between about 50 psi and 100 psi) and the pressure of the freezer
evaporator stream is about 15 psi, the output of the refrigerant stream combining device 416 is at a pressure greater than about 15 psi and less than about 50 psi, e.g., about 30 psi with appropriate energy conversion in the device. Thus, the result of the refrigerant stream combining device is that the device yields an output stream having a pressure that is higher than the pressure of the lower of the two input streams.

[0052] FIG. 6 is a diagram of a dual evaporator refrigeration system, in accordance with yet another embodiment of the invention. It is to be understood that the dual evaporator refrigeration system 600 of FIG. 6 may be implemented in the refrigerator 100 in FIG. 1. That is, one of the two evaporators is used in the freezer compartment 102 and the other one is used in the fresh food compartment 104.

[0053] It is to be understood that the components of the refrigeration system 600 shown in FIG. 6 are generally similar in function to the components of the refrigeration system 200 shown in FIG. 2 and the refrigeration system 400 shown in FIG. 4, with the exception of the features to be described herein below. As such, the reference numerals of components have simply been incremented by 200, i.e., compressor 602 is generally similar to compressor 202/402, condenser 604 is generally similar to condenser 204/404, first and second reducers 606 and 610 are generally similar to first and second reducers 206/406 and 210/410, freezer evaporator 612, fan 613, fresh food evaporator 614 and fan 615 are generally similar to freezer evaporator 212/412, fan 213/413, fresh food evaporator 214/414 and fan 215/415. One will note that a main difference between the embodiments of FIGS. 2 and 4 and the embodiment of FIG. 6 is that system 600 uses a phase separator 608 to separate refrigerant into a predominantly vapor stream and a predominantly liquid stream, which are used as respective motive forces in two refrigerant stream combining devices 616 and 617 positioned at the input of the fresh food evaporator 614. These combining devices are shown as separate for illustration, but the same goal can be accomplished by using two jets in a single refrigerant combining device where one jet is designed and sized to handle liquid refrigerant and the other jet for vapor refrigerant.

[0054] Thus, as shown in FIG. 6, the output of the condenser 604 is provided to the first reducer 606. The output of the first reducer 606 is provided to the phase separator 608. The predominantly liquid refrigerant output by the phase separator 608 is provided to the second reducer 610 and the refrigerant stream combining device 616. The predominantly vapor refrigerant output by the phase separator 608 is provided to the refrigerant stream combining device 617.

[0055] The output of the second reducer 610 is provided to the freezer evaporator 612. The refrigerant passing through the freezer evaporator absorbs the heat in the freezer compartment, as explained above, and exits the freezer evaporator 612.

[0056] In accordance with this illustrative embodiment of the invention, the refrigerant stream exiting the freezer evaporator 612 and the refrigerant stream exiting the first reducer 606 are combined. However, in contrast to system 400 in FIG. 4, here the stream exiting the first reducer is split into a predominantly liquid phase and a predominantly vapor phase. The pressure of the liquid phase refrigerant exiting the first reducer 606 is used to raise the pressure of the refrigerant leaving the freezer evaporator, via use of the combining device 616. The pressure of the vapor phase refrigerant exiting the first reducer is used to raise the pressure of the refrigerant leaving the combining device 616, via use of the combining device 617. Thus, the two combining devices create two venturi stages. The output of the combining device 617 is then used to cool the fresh food evaporator 614. The refrigerant exiting the fresh food evaporator 614 is then routed to the compressor 602 such that the refrigeration cycle is repeated. It is to be understood that while two separate combining devices 616 and 617 are shown in FIG. 6, a two stage combining device that incorporates the functions of combining devices 616 and 617 may be employed.

[0057] FIG. 7 is a diagram illustrating refrigerant flow associated with the refrigerant stream combining devices in the dual evaporator refrigeration system of FIG. 6. Note that, in this embodiment, the diameter of the liquid jet (nozzle) is smaller than that of the vapor jet (nozzle); however, the dimensions of the device may be the same or similar to those described above in the context of FIGS. 3 and 5. As shown, the liquid refrigerant stream exiting the phase separator 608 is provided to a first input 702 of the refrigerant stream combining device 616. This stream is called the “motive fluid.” Further, the refrigerant stream exiting the freezer evaporator 612 is provided to a second input 704 of the refrigerant stream combining device 616. This stream is called the “suction fluid.” The motive fluid is therefore at a higher pressure than the suction fluid. The liquid jet and the vapor jet might also be side by side.

[0058] In operation, the refrigerant stream combining device 616 accelerates the liquid refrigerant stream from the phase separator, thus pulling in the lower pressure refrigerant from the freezer evaporator. A refrigerant stream is output by the combining device 616 at output 706. This stream serves as the suction fluid that is pulled into input 710 of combining device 617 by the accelerated vapor refrigerant (motive fluid) coming from the phase separator 608 and entering input 708 of the combining device 617. The stream exiting combining device 617 at output 712 is thus at a pressure that is higher than the pressure of the refrigerant exiting the freezer evaporator 612.

[0059] By way of example, assuming the pressure of the first reducer stream is about 50 psi (e.g., can range between about 50 psi and 100 psi) and the pressure of the freezer stream is about 15 psi, the output of the refrigerant stream combining device 617 is at a pressure greater than about 15 psi and less than about 50 psi, e.g., about 30 psi with appropriate energy conversion in the two combining devices. Thus, the result of each refrigerant stream combining devices is that the device yields an output stream having a pressure that is higher than the pressure of the lower of the two input streams.

[0060] FIG. 8 is a diagram of a dual evaporator refrigeration system, in accordance with a further embodiment of the invention. It is to be understood that the dual evaporator refrigeration system 800 of FIG. 8 may be implemented in the refrigerator 100 in FIG. 1. That is, one of the two evaporators is used in the freezer compartment 102 and the other one is used in the fresh food compartment 104.

[0061] It is to be understood that the components of the refrigeration system 800 shown in FIG. 8 are generally similar in function to the components of the refrigeration system 200 shown in FIG. 2, with the exception of the features to be described herein below. As such, the reference numerals of components have simply been incremented by 800, i.e., compressor 802 is generally similar to compressor 202, condenser 804 is generally similar to condenser 204, first and second reducers 806 and 810 are generally similar to first and second reducers 806 and 810, phase separator 808 is generally similar
lar to phase separator 208, and freezer evaporator 812, fan 813, fresh food evaporator 814 and fan 815 are generally similar to freezer evaporator 212, fan 213, fresh food evaporator 214 and fan 215.

[0062] While the operation of system 800 is the same as or similar to the operation of system 200 (described above, and thus is not be repeated here), one will note that a main difference between the embodiment of FIG. 2 (system 200) and the embodiment of FIG. 8 (system 800) is that the phase separator is positioned at the input of the fresh food evaporator in FIG. 2 and at the output of the fresh food evaporator in FIG. 8. However, the phase separator 808 provides the same advantage as in the FIG. 2 embodiment of more high pressure versus low pressure refrigerant flow. With regard to design conditions, each configuration would provide the same energy benefit. There may, however, be some situations where the FIG. 8 embodiment is preferred over the FIG. 2 embodiment, or vice versa, based on geometry considerations. For example, the required length of tubes might be shorter for one configuration on a bottom mount freezer and another configuration on a top mount freezer.

[0063] Another difference between system 200 and system 800 is that, in system 800, all the refrigerant flows through the fresh food evaporator 814 and then less than about half is split off to go to the freezer evaporator 812 (note that freezer evaporator gets predominantly liquid phase part from phase separator and combining device gets predominantly vapor phase part from phase separator). In contrast, in system 200, each evaporator only receives the refrigerant flow required to cool its respective compartment. As such, system 800 may perform better in off design conditions such as when only one compartment requires cooling.

[0064] Lastly, as shown in FIG. 8, the lower pressure stream output from the freezer evaporator 812 is the suction fluid input to the combining device 816, while one of the outputs of the phase separator 808 (higher pressure) is the motive fluid input to the device 816.

[0065] Note that the refrigerant stream combining device 816 in FIG. 8 can have the same configuration as the device shown in FIG. 3.

[0066] It is to be appreciated that one ordinarily skilled in the art will realize that well-known heat exchange and heat transfer principles may be applied to determine appropriate dimensions and materials of the various assemblies illustratively described herein, as well as flow rates of refrigerant that may be appropriate for various applications and operating conditions, given the inventive teachings provided herein. While methods and apparatus of the invention are not limited thereto, the skilled artisan will realize that such rates, dimensions and materials may be determined and selected in accordance with well-known heat exchange and heat transfer principles as described in R. K. Shah, “Fundamentals of Heat Exchanger Design,” Wiley & Sons, 2003 and F. P. Incropera et al., “Introduction to Heat Transfer,” Wiley & Sons, 2006, the disclosures of which are incorporated by reference herein.

[0067] It is to be further appreciated that the refrigeration systems described herein may have control circuitry including, but not limited to, a microprocessor (processor) that is programmed, for example, with suitable software or firmware, to implement one or more techniques as described herein. In other embodiments, an ASIC (Application Specific Integrated Circuit) or other arrangement could be employed. One of ordinary skill in the art will be familiar with refrigeration systems and given the teachings herein will be enabled to make and use one or more embodiments of the invention; for example, by programming a microprocessor with suitable software or firmware to cause the refrigeration system to perform illustrative steps described herein. Software includes but is not limited to firmware, resident software, microcode, etc. It is to be further understood that part or all of one or more features of the invention discussed herein may be distributed as an article of manufacture that itself comprises a tangible computer readable recordable storage medium having computer readable code means embodied therein. The computer readable program code means is operable, in conjunction with a computer system or microprocessor, to carry out all or some of the steps to perform the methods or create the apparatuses discussed herein. A computer usable medium may, in general, be a recordable medium (e.g., floppy disks, hard drives, compact disks, EEPROMs, or memory cards) or may be a transmission medium (e.g., a network comprising fiber-optics, the worldwide web, cables, or a wireless channel using time-division multiple access, code-division multiple access, or other radio-frequency channel). Any medium known or developed that can store information suitable for use with a computer system may be used. The computer-readable code means is any mechanism for allowing a computer or processor to read instructions and data, such as magnetic variations on magnetic media or height variations on the surface of a compact disk. The medium can be distributed on multiple physical devices. As used herein, a tangible computer-readable recordable storage medium is intended to encompass a recordable medium, examples of which are set forth above, but is not intended to encompass a transmission medium or disembodied signal. A microprocessor may include and/or be coupled to a suitable memory.

[0068] Furthermore, it is also to be appreciated that methods and apparatus of the invention may be implemented in electronic systems under control of one or more microprocessors and computer readable program code, as described above, or in electromechanical systems where operations and functions are under substantial control of mechanical control systems rather than electronic control systems.

[0069] Thus, while there have been shown and described and pointed out fundamental novel features of the invention as applied to exemplary embodiments thereof, it will be understood that various omissions and substitutions and changes in the form and details of the devices illustrated, and in their operation, may be made by those skilled in the art without departing from the spirit of the invention. Moreover, it is expressly intended that all combinations of those elements and/or method steps which perform substantially the same function in substantially the same way to achieve the same results are within the scope of the invention. Furthermore, it should be recognized that structures and/or elements and/or method steps shown and/or described in connection with any disclosed form or embodiment of the invention may be incorporated in any other disclosed or described or suggested form or embodiment as a general matter of design choice. It is the intention, therefore, to be limited only as indicated by the scope of the claims appended hereto.

1. A dual evaporator refrigerator appliance comprising:
   a first evaporator;
   a second evaporator;
   a phase separator coupled to an input of the first evaporator and an input of the second evaporator, wherein the phase separator provides a refrigerant stream in a vapor phase
part and a liquid phase part to the input of the first evaporator and a refrigerant stream in a liquid phase to the input of the second evaporator;
a refrigerant stream combining device coupled to an output of the first evaporator and an output of the second evaporator, wherein the refrigerant stream combining device receives a first refrigerant stream having a first pressure from the output of the first evaporator and a second refrigerant stream having a second pressure from the output of the second evaporator, and generates an output refrigerant stream having a pressure greater than the second pressure.

2. The dual evaporator refrigerator appliance of claim 1, wherein the pressure of the output refrigerant stream is also less than the first pressure.

3. The dual evaporator refrigerator appliance of claim 1, further comprising a first reducer, wherein an output of the first reducer is coupled to an input of the phase separator and one output of the phase separator is coupled to the input of the first evaporator.

4. The dual evaporator refrigerator appliance of claim 3, further comprising a condenser, wherein an output of the condenser is coupled to an input of the first reducer.

5. The dual evaporator refrigerator appliance of claim 4, further comprising a second reducer, wherein an input of the second reducer is coupled to another output of the phase separator and an output of the second reducer is coupled to the input of the second evaporator.

6. The dual evaporator refrigerator appliance of claim 5, further comprising a compressor, wherein an output of the compressor is coupled to an input of the condenser and an input of the compressor is coupled to an output of the refrigerant stream combining device.

7. The dual evaporator refrigerator appliance of claim 1, wherein the first evaporator is a fresh food evaporator.

8. The dual evaporator refrigerator appliance of claim 1, wherein the second evaporator is a freezer evaporator.

9. The dual evaporator refrigerator appliance of claim 1, wherein the refrigerant stream combining device comprises a Venturi jet pump device.

10. The dual evaporator refrigerator appliance of claim 1, wherein the phase separator increases an amount of high pressure refrigerant that acts as a motive medium in the refrigerant stream combining device and decreases an amount of suction medium entering the refrigerant stream combining device.

11. A dual evaporator refrigerator appliance comprising: a first evaporator; a second evaporator; and a refrigerant stream combining device coupled between an output of the second evaporator and an input of the first evaporator, wherein the refrigerant stream combining device receives a first refrigerant stream having a first pressure and receives a second refrigerant stream having a second pressure from the output of the second evaporator, and generates an output refrigerant stream having a pressure greater than the second pressure, the output refrigerant stream being provided to the input of the first evaporator.

12. The dual evaporator refrigerator appliance of claim 11, wherein the pressure of the output refrigerant stream is less than the first pressure.

13. The dual evaporator refrigerator appliance of claim 11, further comprising a first reducer, wherein an output of the first reducer is coupled to one input of the refrigerant stream combining device such that the refrigerant stream combining device receives the first refrigerant stream having the first pressure from the first reducer.

14-16. (canceled)

17. The dual evaporator refrigerator appliance of claim 11, wherein the first evaporator is a fresh food evaporator.

18. The dual evaporator refrigerator appliance of claim 11, wherein the second evaporator is a freezer evaporator.

19. A dual evaporator refrigerator appliance comprising: a first evaporator; a second evaporator; a phase separator; a first refrigerant stream combining device; and a second refrigerant stream combining device; wherein one output of the phase separator is coupled to one input of the first refrigerant stream combining device and another output of the phase separator is coupled to one input of the second refrigerant stream combining device, and an output of the second evaporator is coupled to another input of the second refrigerant stream combining device while an output of the second refrigerant stream combining device is coupled to another input of the first refrigerant stream combining device, and an output of the first refrigerant stream combining device is coupled to an input of the first evaporator; and wherein the phase separator provides a refrigerant stream in one phase and a refrigerant stream in another phase that are respectively used by the first and second refrigerant stream combining devices to generate an output refrigerant stream having a pressure that is greater than a pressure of a refrigerant stream output by the second evaporator, the output refrigerant stream being input to the first evaporator.

20. The dual evaporator refrigerator appliance of claim 19, wherein the one phase of the refrigerant stream input to the first refrigerant stream combining device is a predominantly vapor phase.

21. The dual evaporator refrigerator appliance of claim 19, wherein the other phase of the refrigerant stream input to the second refrigerant stream combining device is a predominantly liquid phase.

22. The dual evaporator refrigerator appliance of claim 19, wherein the first evaporator is a fresh food evaporator.

23. The dual evaporator refrigerator appliance of claim 19, wherein the second evaporator is a freezer evaporator.

24. (canceled)