APPARATUS FOR CONTROLLING RELATIVE HUMIDITY IN A CONTAINER

In one embodiment, the invention provides a refrigeration system having a compressor configured to compress a refrigerant gas and a condenser fluidly coupled to the compressor to receive compressed refrigerant gas from the compressor, the condenser configured to condense the refrigerant gas. In addition, the refrigeration system includes a heat exchanger having a first section fluidly coupled to the compressor, and a second section fluidly coupled between the condenser and the compressor, wherein the first section receives compressed refrigerant gas from the compressor, and wherein the second section receives condensed refrigerant from the condenser, evaporates the refrigerant, and delivers the evaporated refrigerant to the compressor.
APPARATUS FOR CONTROLLING RELATIVE HUMIDITY IN A CONTAINER

CROSS-REFERENCE TO RELATED APPLICATIONS


BACKGROUND

[0002] Transporting and storing temperature sensitive cargo over periods of time may require a controlled climate in the space where the cargo is loaded. Climate control includes controlling the temperature of the cargo to be within a certain predefined acceptable range. Controlling the temperature includes bringing the temperature of the cargo into an acceptable range (by refrigerating or heating) and maintaining the temperature within that range. Climate control may also include controlling the humidity of the space where cargo is loaded.

[0003] The temperature of temperature sensitive cargo should be kept within predefined acceptable limits. Some cargo must be maintained frozen, and the temperature of any part of the frozen cargo must be kept below a predefined freezing temperature which depends on the cargo, e.g., below 10 degrees Fahrenheit or lower, while commodities such as fresh fruit and vegetables should be kept chilled, but not frozen, to stay fresh.

[0004] During operation of a refrigeration system, water vapor will condense on the evaporator and form a layer of ice that will degrade the efficiency of the evaporator and thereby of the refrigeration system. The ice is removed by running a defrosting cycle. Traditionally, defrosting cycles are initiated according to a predetermined schedule at time intervals which may depend on the nature of the cargo and the time since its loading into the container.

[0005] Some cargoes need relative humidity to be kept below acceptable upper limits. Some of these cargoes are also sensitive to temperatures, while others are relatively insensitive to temperature. Examples of such products are electronic and optical products, scientific instruments, machinery and metals such as iron and steel that may corrode if the relative humidity is too high, clothing and other textiles where fungus growth can be prevented by keeping the relative humidity low.

SUMMARY

[0006] In one embodiment, the invention provides a refrigeration system having a compressor configured to compress a refrigerant gas and a condenser fluidly coupled to the compressor to receive compressed refrigerant gas from the compressor, the condenser configured to condense the refrigerant gas. In addition, the refrigeration system includes a heat exchanger having a first section fluidly coupled to the compressor, and a second section fluidly coupled between the condenser and the compressor, wherein the first section receives compressed refrigerant gas from the compressor, and wherein the second section receives condensed refrigerant from the condenser, evaporates the refrigerant, and delivers the evaporated refrigerant to the compressor.

[0007] In another embodiment, the invention provides a method of operating a refrigeration system, the method including compressing a refrigerant with a compressor and condensing compressed refrigerant gas from the compressor in a condenser. The method further includes receiving into a first section of a heat exchanger compressed refrigerant gas from the compressor, evaporating condensed refrigerant from the condenser in a second section of the heat exchanger, and delivering the evaporated refrigerant from the second section to the compressor.

[0008] In yet another embodiment, the invention provides a method of operating a refrigeration system, the method including measuring a relative humidity of a container. In addition, the method includes comparing the measured relative humidity to a humidity set point, and operating evaporator fans of a refrigeration system when the measured relative humidity is above the humidity set point.

[0009] Other aspects of the invention will become apparent by consideration of the detailed description and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. 1 is a perspective view of a container for transporting cargo.

[0011] FIG. 2 is a schematic view of a refrigeration system which includes a dehumidification system.

DETAILED DESCRIPTION

[0012] Before any embodiments of the invention are explained in detail, it is to be understood that the invention is not limited in its application to the details of construction and the arrangement of components set forth in the following description or illustrated in the following drawings. The invention is capable of other embodiments and of being practiced or being carried out in various ways.

[0013] FIG. 1 is a perspective view of a container 100 that is used for transporting cargo of various types. Coupled to one end of the container is a refrigeration system 10 which is used to control the climate, including the humidity level, of the interior of the container 100. The container 100 could alternatively be a trailer, a railroad car, a straight truck cargo space, or other storage compartment used to transport cargo.

[0014] FIG. 2 is a schematic view of the refrigeration system 10 which includes a dehumidification system. The illustrated embodiment includes a refrigeration system 10 with a compressor 20 which in operation compresses a refrigerant used in the refrigeration system 10. Compressed and hot refrigerant is conducted from the compressor 20 through conduits 21 and 31 to a condenser 30 where heat energy is removed from the refrigerant. The shown condenser 30 is fan assisted, and condensed and cooled refrigerant leaves the condenser 30 through a conduit 32 and enters a receiver tank 33. If additional cooling of the refrigerant is desired, an optional water-cooled condenser 30' (shown in a dash-line frame) may be used. From the receiver tank 33 (or optionally the water-cooled condenser 30') the condensed refrigerant is conducted through a conduit 34 (e.g., a liquid line) through a drier oil filter 35 to an economizer heat exchanger 40 and through a conduit 41 and a thermostatic expansion valve 42 to an evaporator 50. Fans 55 circulate the air through the evaporator 50 and through the interior of the container 100 in a direction shown by the arrows.
The evaporator 50 has a first part 102 and a second part 104. The evaporator 50 is a tube-fin-type heat exchanger. The refrigerant in the first part 102 and the second part 104 remains separate until the refrigerant reaches a discharge point 105. Thus, the refrigerant contained in the tubes of the first part 102 does not mix with any refrigerant contained in the tubes of the second part 104 until the refrigerant cycles through the first part 102 or the second part 104 to the discharge point 105, where the tubes of the first and second parts 102, 104 combine into a discharge header, for example. When the refrigerant reaches the discharge point 105 the refrigerant from the first part 102 and the second part 104 mixes and is returned to the compressor 20 via a return conduit 22. However, the first part 102 and the second part 104 are thermally connected. In other words, the fins that assist in transferring heat to and from the tubes are interconnected between both the tubes of the first and second parts 102, 104 of the evaporator 50.

The refrigeration system 10 has a first distributor 51 and a second distributor 52 each of which is connected to receive cold condensed refrigerant from the conduit 41 and the thermostatic expansion valve 42. The first distributor 51 feeds refrigerant to the tubes of the first part 102 of the evaporator 50, and the second distributor 52 feeds refrigerant to the tubes of the second part 104 of the evaporator 50. On its upstream side the first distributor 51 is connected to a first control valve 53. A second control valve 54 is connected to the conduit 21 that conducts hot compressed refrigerant gas from the compressor 20 to the second control valve 54. A conduit 56 connects the outlet of the second control valve 54 with the inlet of the first distributor 51.

In an alternative construction the refrigeration system does not include the first control valve 53 and the first section 102 is not connected to the conduit 41 that conducts refrigerant from the economizer 40 and the condenser 30. Thus, in this alternative construction, if the second control valve 54 is open then hot refrigerant is received into the first section 102. If the second control valve 54 is closed, then no refrigerant whatsoever is circulated through the first section 102.

A controller 110 controls the operation of the refrigeration system 10. A thermometer 108 measures the temperature of the interior of the container 100 and relays the temperature to the controller 110. An electric heating element 60 is arranged adjacent the evaporator 50. A humidity sensor 106 is arranged for sensing the relative humidity of the air in the container 100 and outputs a corresponding signal to the controller 110 for determining whether the relative humidity is within acceptable limits.

The refrigeration system 10 addresses the problem of reducing the relative humidity, in particular when the cargo is relatively insensitive to temperature. The method of the invention uses a refrigeration system and operates the refrigeration system to cause the temperature of the air to increase whereby the relative humidity is reduced. Preferably, the evaporator fans 55 are initially operated to cause the air to circulate within the container 100. The friction heat that is generated by the circulating air will cause the temperature to increase and in consequence the relative humidity will decrease. The refrigeration system 10 may further be operated to activate the electric heating element 60. This use of the refrigeration system 10 for heating the air to reduce the relative humidity without refrigerating or dehumidifying is advantageous and allows a refrigeration system to be used for other purposes than refrigeration and other traditional uses.

If it is determined that the relative humidity is higher than desired, i.e. higher than a predetermined value, heat generating means of the refrigeration system 10 are activated to heat the air in the container and thereby reduce the relative humidity. Humidity is not extracted from the air by heating alone and the absolute humidity will remain constant, but since the capacity of the air to absorb or contain water vapor increases with increasing temperature, the relative humidity will decrease with increasing temperature.

Specifically, the heat generating means of the refrigeration system 10 that are activated to heat the air in the container 100 comprises one or more of the fans 55 that are arranged to circulate the air in the container 100 past the evaporator 50 and through the container 100. Circulating the air in the container 100 requires energy which is dissipated as heat due to friction between the air and the container walls and the cargo in the container 100. The dissipated heat will increase the temperature of the air and the relative humidity will thereby be correspondingly reduced.

If the friction heat generated using one or more of the fans 55 to circulate the air in the container 100 is not enough to keep the relative humidity below the predetermined acceptable value, the electric heating element 60 may additionally be activated. The fan/fans 55 circulate the air in the container 100 past the heating element 60 whereby the air is further heated in addition to the friction heat generated by circulating the air.

The refrigeration system 10 also addresses the problem of reducing the relative humidity, in particular when the cargo is sensitive to temperature. This invention is useful for dehumidifying the air in the container 100 while still maintaining the cargo chilled. For example, fresh fruit generates water vapor that needs to be removed by dehumidification for which traditionally the refrigeration system is used. Dehumidification is done by operating the refrigeration system in a first mode to refrigerate the air whereby water vapor condensates on the evaporator coil. In case of high humidity, elevated dehumidification will be necessary which involves running one or more sections of the evaporator coil at correspondingly elevated refrigeration power in order to condensate the water vapor. Thereby the air may become refrigerated below a critical minimum temperature (e.g. bananas must be kept at a temperature not lower than 13 degrees C.). Refrigeration below the critical minimum temperature must be avoided. Traditionally, in order to compensate for the elevated refrigeration an electric heating element is activated. Instead, according to the invention, heating energy already produced by the refrigeration system 10 is used. When the refrigerant leaves the compressor it is “hot” and traditionally all the hot refrigerant is condensed and cooled in the condenser where a condenser fan removes the heat before the “cold” refrigerant is conducted to the evaporator. According to the invention, the refrigeration system will operate in a second mode of operation where a portion of the compressed refrigerant from the compressor bypasses the condenser and is fed to a section of the evaporator coil as “hot gas”.

In the first mode of operation the first control valve 53 is open and the second control valve 54 is closed. The refrigerant will then flow in the closed circuit from the compressor 20 through conduits 21 and 31, condenser 30, receiver tank 33, conduit 34, drier oil filter 35, heat exchanger 40, conduit 41, expansion valve 42, first and second distributors
51, 52, first part 102 and second part 104 of the evaporator 50 and return conduit 22 back to the compressor 20. The first mode of operation is thus a traditional refrigeration mode where both the first and the second distributor 51, 52 receive cold refrigerant which is fed into both the first and the second parts 102, 104 of the evaporator 50.

[0025] In the second mode of operation the first control valve 53 is closed, and the first distributor 51 will no longer receive cold refrigerant as in the first mode of operation. The second control valve 54 is opened so that hot refrigerant from the compressor will be conducted through conduit 21, the second control valve 54 and conduit 55 to the inlet of the first distributor 51 and into the first part 102 of the evaporator 50. The second distributor 52 and the second part 104 of the evaporator 50 will still receive cold refrigerant like in the first mode of operation described above. Thus the second part 104 of the evaporator 50 can be operated to achieve the desired temperature. If the air in the container 100 is thereby refrigerated to an unacceptable low temperature, the second control valve 54 is opened to conduct hot refrigerant to the first part 102 of the evaporator 50 whereby the air that is drawn through the evaporator 50 by means of the fans 55 will be heated to raise the temperature of the air in the interior of container 100. Thus the air in the interior of the container 100 is controlled to be at a desired relative humidity level.

[0026] The refrigeration system 10 may also be used to defrost the evaporator 50 when ice has accumulated on the evaporator 50. In order to defrost the evaporator 50, the supply of cold refrigerant to the evaporator 50 is stopped and hot refrigerant from the compressor 20 is sent to the first part 102 of the evaporator 50 as described above. As the evaporator 50 is not receiving any cold refrigerant, the heat from the hot refrigerant in the first part 102 of the evaporator 50 will warm the entire evaporator 50, thus melting the ice from the evaporator 50.

[0027] Thus, the invention provides, among other things, an apparatus for controlling humidity in a container. Various features and advantages of the invention are set forth in the following claims.

What is claimed is:

1. A refrigeration system comprising:
a compressor configured to compress a refrigerant gas;
a condenser fluidly coupled to the compressor to receive compressed refrigerant gas from the compressor, the condenser configured to condense the refrigerant gas;
a heat exchanger having a first section fluidly coupled to the compressor, and a second section fluidly coupled between the condenser and the compressor, wherein the first section receives compressed refrigerant gas from the compressor, and wherein the second section receives condensed refrigerant from the condenser, evaporates the refrigerant, and delivers the evaporated refrigerant to the compressor.

2. The refrigeration system of claim 1, wherein the first section receives condensed refrigerant from the condenser, evaporates the refrigerant, and delivers the evaporated refrigerant to the compressor in a first mode of operation, and wherein the first section receives compressed refrigerant gas from the compressor in a second mode of operation.

3. The refrigeration system of claim 2, wherein the refrigeration system operates in the first mode of operation when the temperature of the container is below a temperature lower limit, and wherein the refrigeration system operates in the second mode of operation when the temperature of the container is above a temperature upper limit and the relative humidity of the container is above a humidity upper limit.

4. The refrigeration system of claim 3, wherein the refrigeration system includes humidity sensor for sensing the relative humidity of the container, and wherein the refrigeration system includes a temperature sensor for sensing the temperature of the container.

5. The refrigeration system of claim 4, further comprising a first valve fluidly coupled between the compressor and the first section.

6. The refrigeration system of claim 5, further comprising a second valve fluidly coupled between the condenser and the first section.

7. The refrigeration system of claim 6, further comprising a controller operably coupled to the first valve, the second valve, the humidity sensor, and the temperature sensor, wherein in the second mode of operation the controller opens the first valve when the temperature sensor senses that the temperature of the container is above a temperature upper limit and the humidity sensor senses that the relative humidity of the container is above a humidity upper limit.

8. The refrigeration system of claim 7, wherein in the second mode of operation the controller closes the second valve.

9. The refrigeration system of claim 7, wherein in the first mode of operation the controller closes the first valve and opens the second valve such that the first and second sections receive condensed refrigerant from the condenser, evaporate the refrigerant, and deliver the evaporated refrigerant to the compressor.

10. A method of operating a refrigeration system, the method comprising:
compressing a refrigerant with a compressor;
condensing compressed refrigerant gas from the compressor in a condenser;
receiving into a first section of a heat exchanger compressed refrigerant gas from the compressor;
evaporating condensed refrigerant from the condenser in a second section of the heat exchanger; and
delivering the evaporated refrigerant from the second section to the compressor.

11. The method of claim 10, further comprising evaporating condensed refrigerant from the condenser in the first section and delivering the evaporated refrigerant from the first section to the compressor in a first mode of operation, and receiving into the first section compressed refrigerant gas from the compressor in a second mode of operation.

12. The method of claim 11, wherein evaporating condensed refrigerant from the condenser in a second section of the heat exchanger, and delivering the evaporated refrigerant from the second section to the compressor in both the first and second modes of operation.

13. The method of claim 11, further comprising operating in the first mode of operation when the temperature of the container is below a temperature lower limit, and operating in the second mode of operation when the temperature of the container is above a temperature upper limit and the relative humidity of the container is above a humidity upper limit.

14. A method of operating a refrigeration system, the method comprising:
measuring a relative humidity of a container;
comparing the measured relative humidity to a humidity set point;
operating evaporator fans of a refrigeration system when the measured relative humidity is above the humidity set point.

15. The method of claim 14, further comprising comparing the measured relative humidity to an elevated humidity set point, and operating an electric heater of the refrigeration system and the evaporator fans when the temperature of the container is above the elevated humidity set point.

16. The method of claim 14, further comprising operating an electric heater of the refrigeration system if operation of the evaporator fans alone is insufficient to lower the relative humidity below the humidity set point.

17. The method of claim 16, further comprising operating the evaporating fans for a period of time when the measured relative humidity is above the humidity set point, and operating the electric heater after the period of time if operation of the evaporator fans alone is insufficient to lower the relative humidity below the humidity set point.

18. The method of claim 14, further comprising operating the evaporator fans while not operating a compressor of the refrigeration system.

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