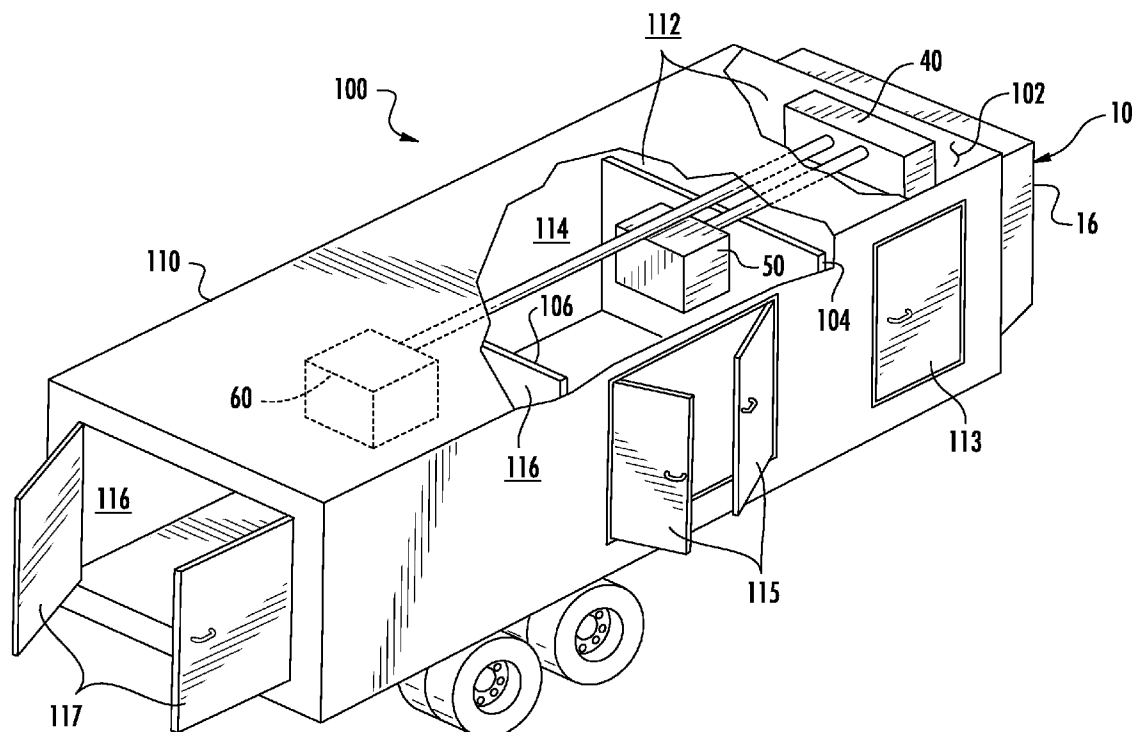


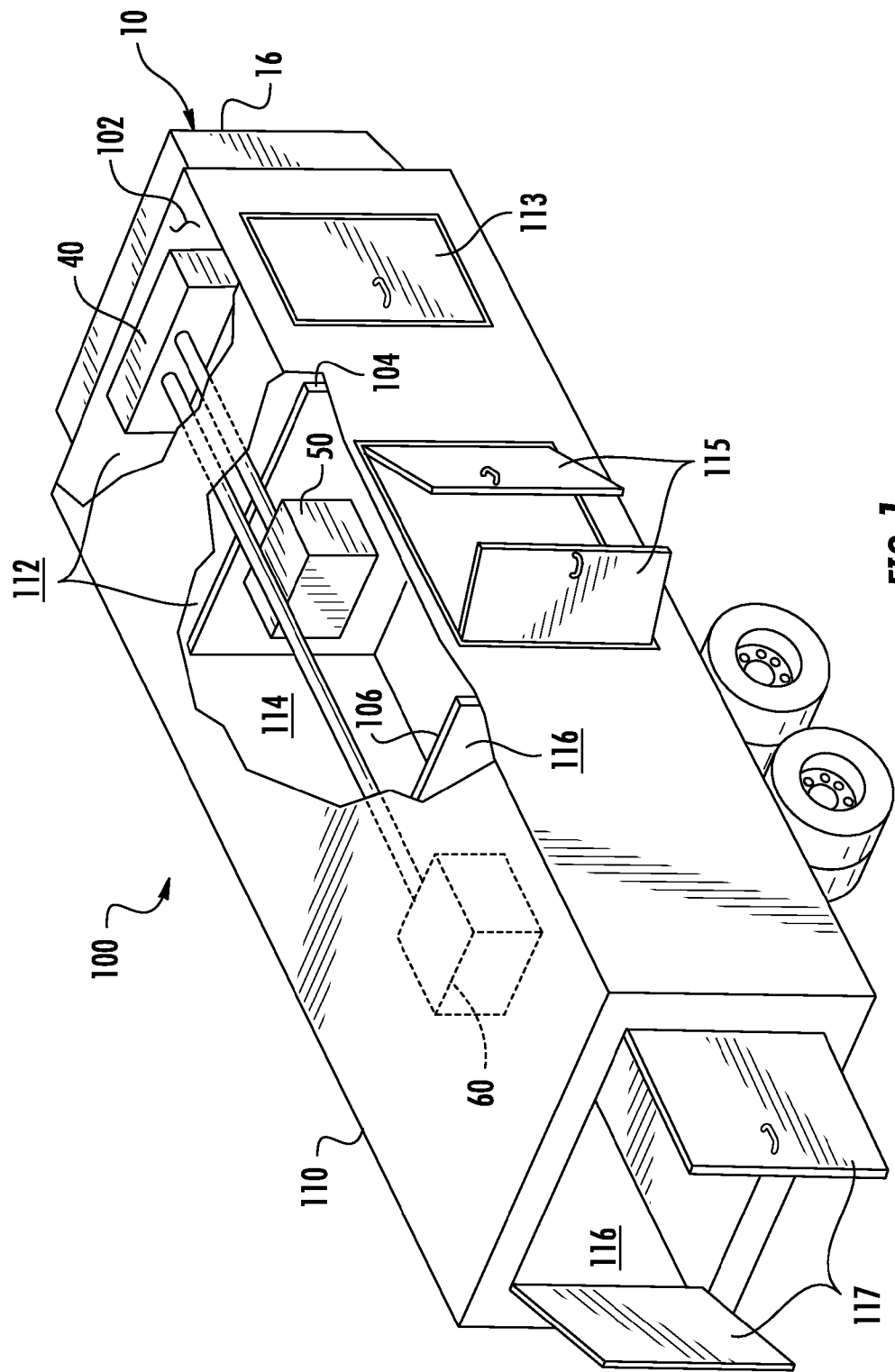


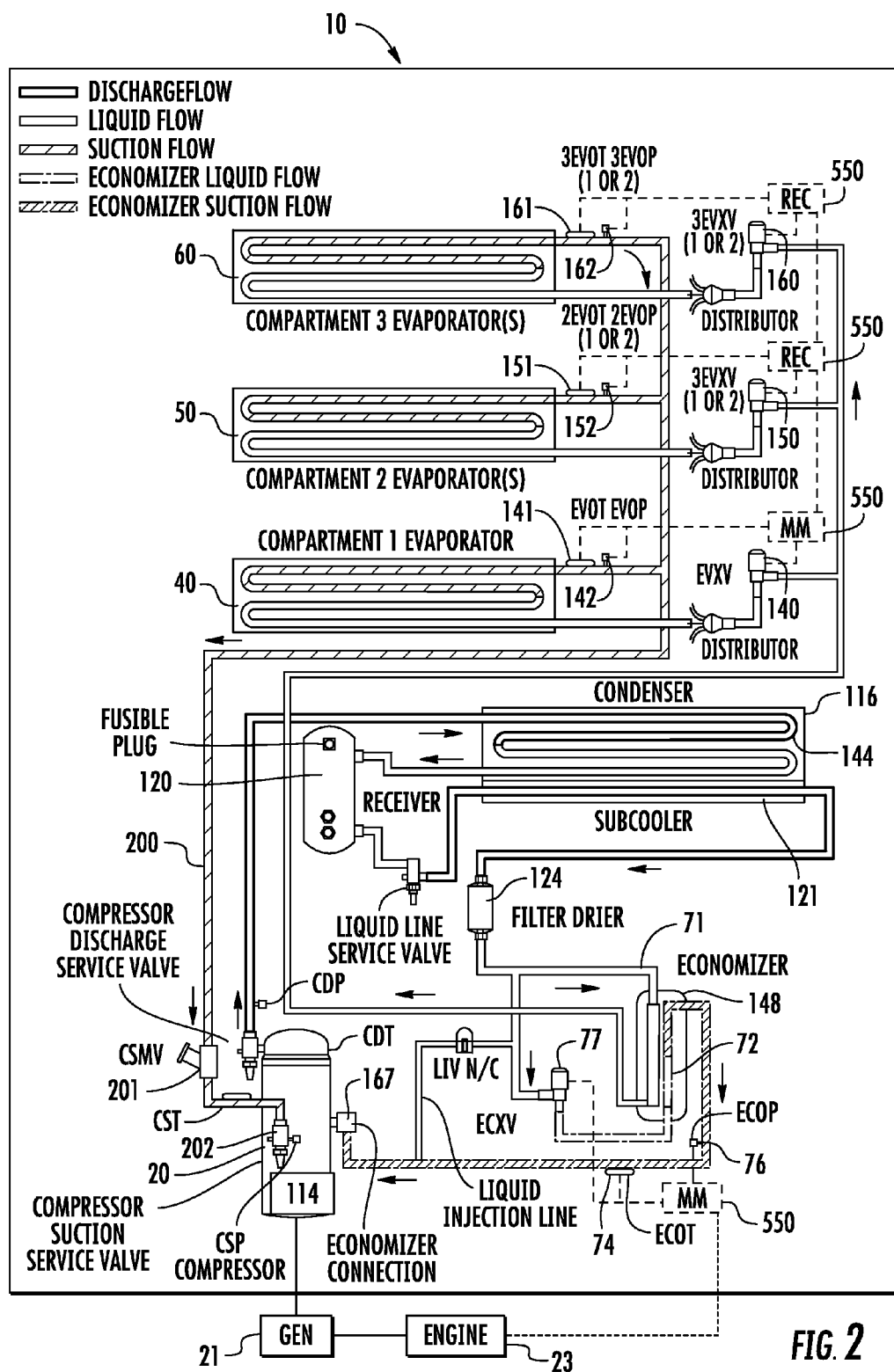
US 20150338154A1

(19) **United States**(12) **Patent Application Publication**
Senf et al.(10) **Pub. No.: US 2015/0338154 A1**(43) **Pub. Date: Nov. 26, 2015**(54) **MULTI-COMPARTMENT TRANSPORT
REFRIGERATION SYSTEM WITH
ECONOMIZER****Publication Classification**(51) **Int. Cl.**
F25D 11/00 (2006.01)
(52) **U.S. Cl.**
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NY (US)(21) Appl. No.: **14/794,339**(22) Filed: **Jul. 8, 2015****Related U.S. Application Data**(63) Continuation-in-part of application No. PCT/US2013/
071641, filed on Nov. 25, 2013.(60) Provisional application No. 61/758,806, filed on Jan.
31, 2013.(57) **ABSTRACT**

A multi-compartment transport refrigeration system includes a compressor having suction port, discharge port and intermediate inlet port; a heat rejecting heat exchanger; an economizer heat exchanger having a first refrigerant flow path and a second refrigerant flow path therethrough; a first evaporator expansion device; a first evaporator having an inlet coupled to the first evaporator expansion device and an outlet coupled to a compressor inlet path, the first evaporator for cooling a first compartment of a container; a second evaporator expansion device, the second evaporator for cooling a second compartment of the container; an economizer expansion device coupled to the first refrigerant flow path, the economizer expansion device directing refrigerant from the first refrigerant flow path to the second refrigerant flow path, the second refrigerant flow path coupled to the intermediate inlet port.







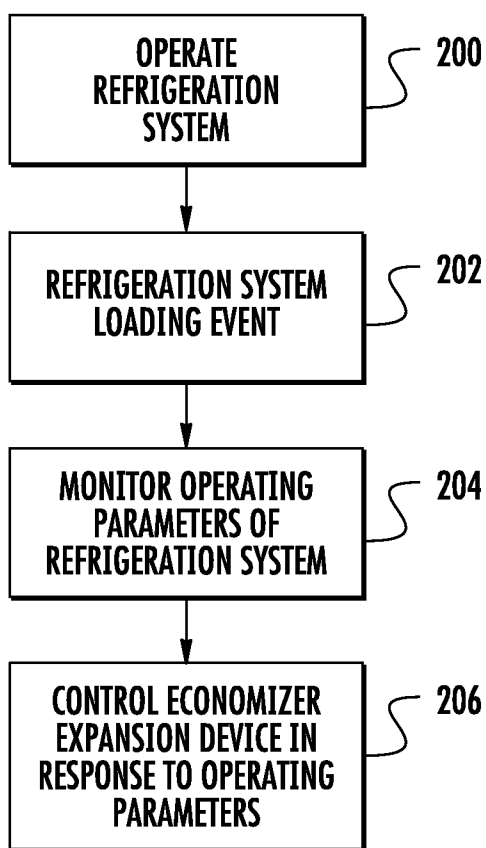


FIG. 3

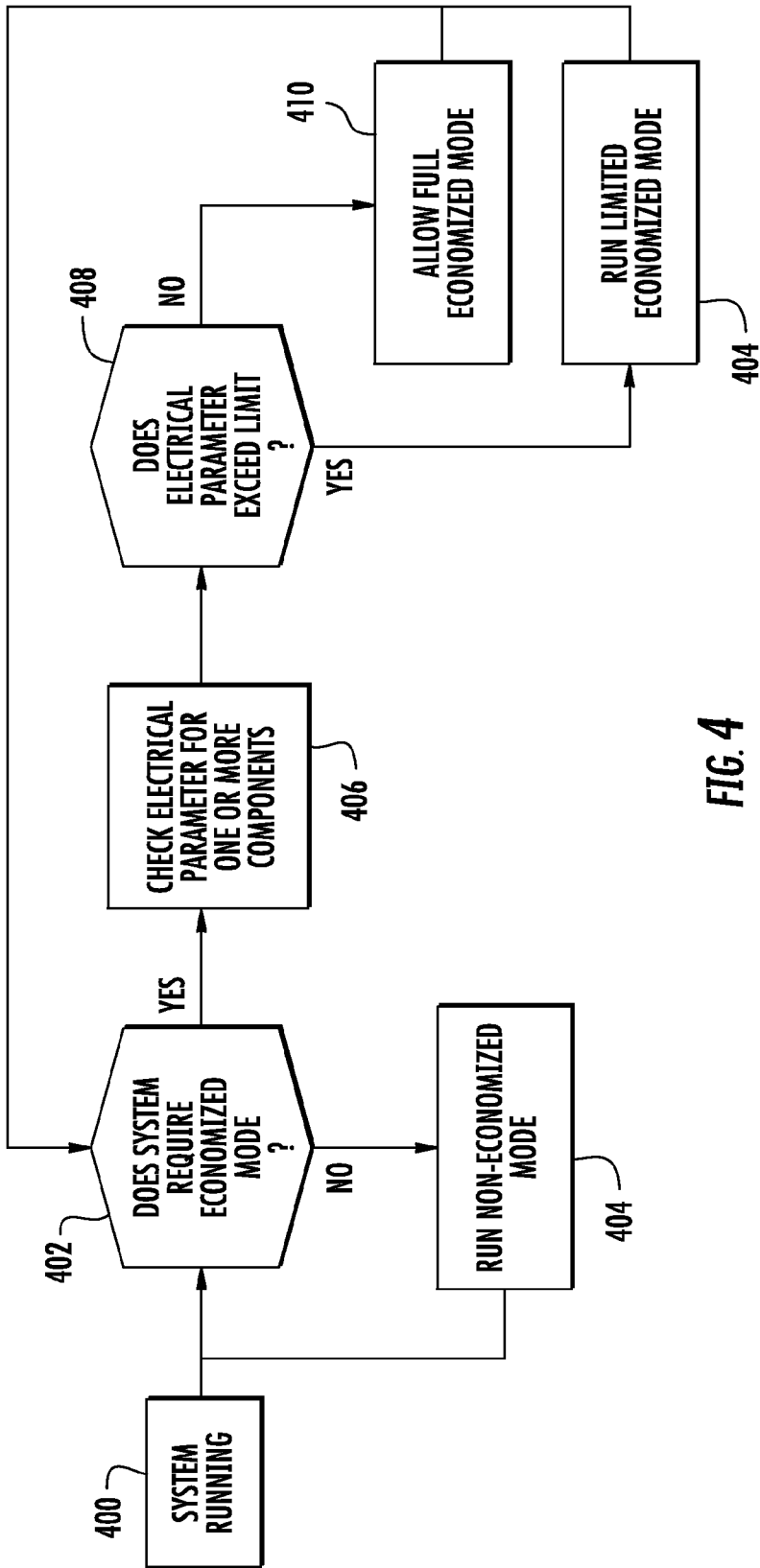


FIG. 4

MULTI-COMPARTMENT TRANSPORT REFRIGERATION SYSTEM WITH ECONOMIZER

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation-in-part of International Patent Application No. PCT/US2013/071641, filed Nov. 25, 2013, which claims the benefit of U.S. Provisional patent application No. 61/758,806, filed Jan. 31, 2013, the entire contents of both applications being incorporated herein by reference.

BACKGROUND

[0002] Embodiments relate generally to transport refrigeration systems, and more particularly to multi-compartment transport refrigeration systems using an economizer.

[0003] The refrigerated container of a truck trailer requires a refrigeration unit for maintaining a desired temperature environment within the interior volume of the container. A wide variety of products, ranging for example, from freshly picked produce to deep frozen seafood, are commonly shipped in refrigerated truck trailers and other refrigerated freight containers. To facilitate shipment of a variety of products under different temperature conditions, some truck trailer containers are compartmentalized into two or more separate compartments each of which will typically have a door that opens directly to the exterior of the trailer. The container may be compartmentalized into a pair of side-by-side axially extending compartments, or into two or more back-to-back compartments, or a combination thereof.

[0004] Conventional transport refrigeration units used in connection with compartmentalized refrigerated containers of truck trailers include a refrigerant compressor, a condenser, a main evaporator and one or more remote evaporators connected via appropriate refrigerant lines in a closed refrigerant flow circuit. The refrigeration unit must have sufficient refrigeration capacity to maintain the perishable product stored within the various compartments of the container at the particular desired compartment temperatures over a wide range of outdoor ambient temperatures and load conditions.

[0005] In addition to the afore-mentioned main evaporator, one or more remote evaporators, typically one for each additional compartment aft of the forward most compartment, are provided to refrigerate the air or other gases within each of the separate aft compartments. The remote evaporators may be mounted to the ceiling of the respective compartments or mounted to one of the partition walls of the compartment, as desired. The remote evaporators are generally disposed in the refrigerant circulation circuit in parallel with the main evaporator. Typically, a solenoid operated shut off valve is disposed in the refrigerant circulation circuit upstream of each of the remote evaporators in operation with a system controller so that each remote evaporator may be independently and selectively open and closed to refrigerant flow in response to the cooling demand of the respective compartment with which the respective remote evaporator is operatively associated. The same effect can be accomplished with independent stepper type control valves (rather than solenoid operated shut off valves) at the inlet of each evaporator coil.

[0006] Multiple temperature compartment transport refrigeration systems create significant control and refrigeration system complexity. Emissions requirements for cleaner die-

sel technology and/or engine power levels require a new approach to refrigeration cycle efficiency and power management. Typically, multiple temperature control of compartments is achieved by a pulse width modulation of an evaporator expansion valve of one or more perishable compartments, while an evaporator expansion valve for a frozen compartment is operating in full cool operation. This specific pulse width modulation control on a single stage compression system creates a dynamic power disruption from a rapid rise in suction pressure at the compressor due to the fact the saturated evaporation temperatures of all compartments are shared with common suction plenum.

BRIEF DESCRIPTION

[0007] According to one embodiment, a multi-compartment transport refrigeration system includes a compressor having a suction port, a discharge port and an intermediate inlet port located at an intermediate location along a compression path between the compressor suction port and the compressor discharge port; a heat rejecting heat exchanger downstream of the compressor discharge port; an economizer heat exchanger having a first refrigerant flow path and a second refrigerant flow path therethrough; a first evaporator expansion device downstream of the first refrigerant flow path; a first evaporator having an inlet coupled to the first evaporator expansion device and an outlet coupled to a compressor inlet path, the compressor inlet path coupled to the compressor suction port, the first evaporator for cooling a first compartment of a container; a second evaporator expansion device downstream of the first refrigerant flow path; a second evaporator having an inlet coupled to the second evaporator expansion device and an outlet coupled to the compressor inlet path, the second evaporator for cooling a second compartment of the container; and an economizer expansion device coupled to the first refrigerant flow path, the economizer expansion device directing refrigerant from the first refrigerant flow path to the second refrigerant flow path, the second refrigerant flow path coupled to the intermediate inlet port.

[0008] In addition to one or more of the features described above, or as an alternative, further embodiments may include a controller configured to control the economizer expansion device to regulate flow of refrigerant along the second refrigerant flow path to the intermediate inlet port.

[0009] In addition to one or more of the features described above, or as an alternative, further embodiments may include wherein the controller is configured to control the economizer expansion device in response to an operating parameter of the refrigeration system.

[0010] In addition to one or more of the features described above, or as an alternative, further embodiments may include wherein the controller is configured to control the economizer expansion device in response to superheat of the economizer heat exchanger.

[0011] In addition to one or more of the features described above, or as an alternative, further embodiments may include an engine to provide power to the compressor;

[0012] wherein the controller is configured to control the economizer expansion device in response to an operating parameter of the engine.

[0013] In addition to one or more of the features described above, or as an alternative, further embodiments may include wherein the controller is configured to control the economizer expansion device in response to a refrigeration system loading event.

[0014] In addition to one or more of the features described above, or as an alternative, further embodiments may include wherein the controller is configured to control the economizer expansion device in response to a pulsed control signal applied to one of the first evaporator expansion device and the second evaporator expansion device.

[0015] In addition to one or more of the features described above, or as an alternative, further embodiments may include wherein the pulsed control signal is a pulse width modulation signal.

[0016] In addition to one or more of the features described above, or as an alternative, further embodiments may include wherein the controller is configured to control the economizer expansion device in response to an electrical parameter of the refrigeration system.

[0017] In addition to one or more of the features described above, or as an alternative, further embodiments may include wherein the electrical parameter of the refrigeration system includes one or more of output current of a generator, output voltage of a generator, current draw of the compressor, input voltage at the compressor, current draw of a heat rejecting heat exchanger fans, input voltage at the heat rejecting heat exchanger fan, current draw of an evaporator fan, input voltage at the evaporator fans, current draw of a heater and input voltage at the heater.

[0018] In addition to one or more of the features described above, or as an alternative, further embodiments may include wherein control of the economizer expansion device in response to the electrical parameter of the refrigeration system includes: comparing the electrical parameter to a limit; operating the economizer expansion device in a full economized mode when the electrical parameter does not exceed the limit; and operating the economizer expansion device in a limited economized mode when the electrical parameter does exceed the limit.

[0019] According to another embodiment, a transport refrigeration system includes compressor having a suction port, a discharge port and an intermediate inlet port located at an intermediate location along a compression path between the compressor suction port and the compressor discharge port; a heat rejecting heat exchanger downstream of the compressor discharge port; an economizer heat exchanger having a first refrigerant flow path and a second refrigerant flow path therethrough; an evaporator expansion device downstream of the first refrigerant flow path; an evaporator having an inlet coupled to the evaporator expansion device and an outlet coupled to a compressor inlet path, the compressor inlet path coupled to the compressor suction port, the evaporator for cooling a compartment of a container; an economizer expansion device coupled to the first refrigerant flow path, the economizer expansion device directing refrigerant from the first refrigerant flow path to the second refrigerant flow path, the second refrigerant flow path coupled to the intermediate inlet port; and a controller configured to control the economizer expansion device to regulate flow of refrigerant along the second refrigerant flow path to the intermediate inlet port, the controller configured to control the economizer expansion device in response to an electrical parameter of the refrigeration system.

[0020] In addition to one or more of the features described above, or as an alternative, further embodiments may include wherein the electrical parameter of the refrigeration system includes one or more of output current of a generator, output voltage of a generator, current draw of the compressor, input

voltage at the compressor, current draw of a heat rejecting heat exchanger fans, input voltage at the heat rejecting heat exchanger fan, current draw of an evaporator fan, input voltage at the evaporator fans, current draw of a heater and input voltage at the heater.

[0021] In addition to one or more of the features described above, or as an alternative, further embodiments may include wherein control of the economizer expansion device in response to the electrical parameter of the refrigeration system includes: comparing the electrical parameter to a limit; operating the economizer expansion device in a full economized mode when the electrical parameter does not exceed the limit; and operating the economizer expansion device in a limited economized mode when the electrical parameter does exceed the limit.

[0022] These and other advantages and features will become more apparent from the following description taken in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] The foregoing and other features, and advantages of the invention are apparent from the following detailed description taken in conjunction with the accompanying drawings in which:

[0024] FIG. 1 is a perspective view, partly in section, of a refrigerated truck trailer having a compartmentalized container and equipped with a transport refrigeration unit having multiple evaporators in an exemplary embodiment;

[0025] FIG. 2 is a schematic representation of a multiple evaporator transport refrigeration unit in an exemplary embodiment;

[0026] FIG. 3 is a flowchart of a method for controlling the multi-compartment refrigeration system in an exemplary embodiment; and

[0027] FIG. 4 is a flowchart of a method for controlling the multi-compartment refrigeration system in an exemplary embodiment.

[0028] The detailed description explains embodiments of the invention, together with advantages and features, by way of example with reference to the drawings.

DETAILED DESCRIPTION OF THE INVENTION

[0029] Referring now to FIG. 1, there is shown a truck trailer 100 having a refrigerated container 110 subdivided, i.e., compartmentalized, by internal partition walls 104, 106 into a forward cargo compartment 112, a central cargo compartment 114 and an aft cargo compartment 116. The cargo compartments 112, 114 and 116 have access doors 113, 115 and 117, respectively, which open directly to the exterior of the truck trailer to facilitate loading of product into the respective cargo compartments 112, 114 and 116. The container 100 is equipped with a transport refrigeration system 10 for regulating and maintaining within each of the respective cargo compartments 112, 114 and 116 a desired storage temperature range selected for the product being shipped therein. Although embodiments will be described herein with reference to the three compartment, refrigerated container, illustrated in FIG. 1, it is to be understood that embodiments may also be used in connection with truck trailers having compartmentalized containers with the cargo compartments arranged otherwise, and also in connection with other refrigerated transport vessels, including for example refrigerated container of a truck, or a refrigerated freight container of com-

partmentalized design for transporting perishable product by ship, rail and/or road transport.

[0030] Transport refrigeration system **10** includes a main evaporator **40** and remote evaporators **50** and **60**. Each of the evaporators **40**, **50** and **60** may comprise a conventional finned tube coil heat exchanger. The transport refrigeration system **10** is mounted as in conventional practice to an exterior wall of the truck trailer **100**, for example the front wall **102** thereof, with the compressor **20** and the heat rejecting heat exchanger **116** (FIG. 2) disposed externally of the refrigerated container **110** in a housing **16**.

[0031] FIG. 2 is a schematic representation of the multiple evaporator transport refrigeration unit **10** in an exemplary embodiment. In the depicted embodiment, compressor **20** is a scroll compressor, however other compressors such as reciprocating or screw compressors are possible without limiting the scope of the disclosure. Compressor **20** includes a motor **114** which may be an integrated electric drive motor driven by a synchronous generator **21** operating at low speed (for example, 45 Hz) or high speed (for example, 65 Hz). Generator **21** may be driven by a diesel engine **23** of a vehicle that tows truck trailer **100**. Alternatively, generator **21** may be driven by a stand-alone engine **23**. In an exemplary embodiment, engine **23** a diesel engine, such as a four cylinder, 2200 cc displacement diesel engine which operates at a high speed (about 1950 RPM) or at low speed (about 1350 RPM).

[0032] High temperature, high pressure refrigerant vapor exits a discharge port of the compressor **20** then moves to a heat rejecting heat exchanger **116** (e.g., condenser or gas cooler), which includes a plurality of condenser coil fins and tubes **144**, which receive air, typically blown by a heat rejecting heat exchanger fan (not shown). By removing latent heat through this step, the refrigerant condenses to a high pressure/high temperature liquid and flows to the receiver **120** that provides storage for excess liquid refrigerant during low temperature operation. From the receiver **120**, the refrigerant flows to a subcooler **121**, which increases the refrigerant subcooling. Subcooler **121** may be positioned adjacent heat rejecting heat exchanger **116**, and cooled by air flow from the heat rejecting heat exchanger fan. A filter-drier **124** keeps the refrigerant clean and dry, and outlets refrigerant to a first refrigerant flow path **71** of an economizer heat exchanger **148**, which increases the refrigerant subcooling. Economizer heat exchanger **148** may be a plate-type heat exchanger, providing refrigerant to refrigerant heat exchange between a first refrigerant flow path **71** and second refrigerant flow path **72**.

[0033] From the first refrigerant flow path **71**, refrigerant flows from the economizer heat exchanger **148** to a plurality of evaporator expansion devices **140**, **150** and **160**, connected in parallel with the first refrigerant flow path **71**. Evaporator expansion devices **140**, **150** and **160** are associated with evaporators **40**, **50** and **60**, respectively, to control ingress of refrigerant to the respective evaporators **40**, **50** and **60**. The evaporator expansion devices **140**, **150** and **160** are electronic evaporator expansion devices controlled by a controller **550**. Controller **550** is shown as distributed for ease of illustration. It is understood that controller **550** may be a single device that controls the evaporator expansion devices **140**, **150** and **160**. Evaporator expansion device **140** is controlled by controller **550** in response to signals from a first evaporator outlet temperature sensor **141** and first evaporator outlet pressure sensor **142**. Evaporator expansion device **150** is controlled by controller **550** in response to signals from a second evaporator outlet temperature sensor **151** and second evaporator outlet

pressure sensor **152**. Evaporator expansion device **160** is controlled by controller **550** in response to signals from a third evaporator outlet temperature sensor **161** and third evaporator outlet pressure sensor **162**. Evaporator fans (not shown) draw or push air over the evaporators **40**, **50** and **60** to condition the air in compartments **112**, **114**, and **116**, respectively.

[0034] Refrigerant vapor from evaporators **40**, **50** and **60** is coupled to a common compressor inlet path **200** coupled to a compressor suction port through a compressor suction modulation valve **201** and compressor suction service valve **202**.

[0035] Refrigeration system **10** further includes a second refrigerant flow path **72** through the economizer heat exchanger **148**. The second refrigerant flow path **72** is connected between the first refrigerant flow path **71** and an intermediate inlet port **167** of the compressor **20**. The intermediate inlet port **167** is located at an intermediate location along a compression path between compressor suction port and compressor discharge port. An economizer expansion device **77** is positioned in the second refrigerant flow path **72**, upstream of the economizer heat exchanger **148**. The economizer expansion device **77** may be an electronic economizer expansion device controlled by controller **550**. When the economizer is active, controller **550** controls economizer expansion device **77** to allow refrigerant to pass through the second refrigerant flow path **72**, through economizer heat exchanger **148** and to the intermediate inlet port **167**. The economizer expansion device **77** serves to expand and cool the refrigerant, which proceeds into the economizer counter-flow heat exchanger **148**, thereby sub-cooling the liquid refrigerant in the first refrigerant flow path **71** proceeding to evaporator expansion devices **140**, **150** and **160**.

[0036] As described in further detail herein, many of the points in the refrigerant vapor compression system **10** are monitored and controlled by a controller **550**. Controller **550** may include a microprocessor and its associated memory. The memory of controller can contain operator or owner preselected, desired values for various operating parameters within the system **10** including, but not limited to, temperature set points for various locations within the system **10** or the container, pressure limits, current limits, engine speed limits, and any variety of other desired operating parameters or limits with the system **10**. In an embodiment, controller **550** includes a microprocessor board that contains microprocessor and memory, an input/output (I/O) board, which contains an analog to digital converter which receives temperature inputs and pressure inputs from various points in the system, AC current inputs, DC current inputs, voltage inputs and humidity level inputs. In addition, I/O board includes drive circuits or field effect transistors ("FETs") and relays which receive signals or current from the controller **550** and in turn control various external or peripheral devices in the system **10**, such as economizer expansion valve **77**, for example.

[0037] A number of refrigeration system loading events may cause the compressor power to exceed compressor power limits. For example, when evaporator expansion devices **140**, **150** and/or **160** are pulsed, this can create a dynamic power disruption from a rapid rise in suction pressure at compressor **20** due to the fact the saturated evaporation temperatures of all compartments are shared with common suction plenum coupled to common compressor inlet path **200**. The pulses applied to evaporator expansion devices **140**, **150** and/or **160** may be pulse width modulation signals or may correspond to pulsing the evaporator expansion devices **140**,

150 and/or **160** from an on state to off state, and vice versa. The disruptions (e.g., a spike in volume of refrigerant at the suction port of compressor **20**) can cause the compressor to compensate and exceed compressor power limits. Other refrigeration system loading events include heater(s) and/or fan(s) cycling on and off within one or more compartments **112**, **114** and **116**. Embodiments use the economizer expansion valve **77** to maintain compressor power levels below a prescribed power limit by varying the injection gas flow rate from the second refrigerant flow path **72** to the intermediate inlet port **167** to maintain a given engine power level.

[0038] In operation, controller **550** monitors superheat of the economizer heat exchanger **148** through an economizer heat exchanger outlet temperature sensor **74** and economizer heat exchanger outlet pressure sensor **76**. A refrigeration system loading event, such as instantaneous pulses at evaporator expansion devices **140**, **150** and/or **160** may cause a suction pressure rise at the suction port of compressor **20**. This results in an increase in middle stage pressure at intermediate inlet port **167**. This increases the pressure at economizer heat exchanger outlet pressure sensor **76**, which is observed by controller **550** as reduced superheat. Controller **550** responds by reducing flow through or closing the economizer expansion valve **77** to maintain superheat of the economizer heat exchanger **148** at a desired level.

[0039] Controller **550** may also monitor speed and/or load on engine **23** and control the economizer expansion valve **77** in response to engine operating parameters, such as engine speed and/or engine load. The engine operating parameters may be sensed by sensors mounted at engine **23**, in communication with controller **550**. For example, controller **550** may detect that the engine **23** has dropped in RPM, indicating a step load on the compressor **20** due to one or more of refrigeration system loading events. In such a case, controller **550** may close or reduce flow through economizer expansion valve **77** to reduce the volume of refrigerant being supplied to compressor **20**. Using operating parameters of engine **23** to control economizer expansion valve **77** may be performed alone, or in combination with the superheat control described herein.

[0040] FIG. 3 is a flowchart of a method for controlling the multi-compartment refrigeration system in an exemplary embodiment. The process begins at **200** where the refrigeration system is operated to control temperature in the multiple compartments. At **202**, a refrigeration system loading event occurs, such as one or more of the evaporator expansion devices **140**, **150** and **160** being pulsed to control flow through the evaporator expansion device(s), heater(s) and/or fan(s) cycling on and off, etc. At **204**, controller **550** monitors operating parameters of the refrigeration system. The operating parameters may include superheat at the outlet of the economizer heat exchanger **148** and/or operating parameters (e.g., speed and/or load) of engine **23**. At **206**, controller **550** controls that economizer expansion device **77** to adjust the flow of refrigerant to the intermediate inlet port **167** of compressor **20**.

[0041] FIG. 4 is a flowchart of a method for controlling the multi-compartment refrigeration system in another exemplary embodiment. In the method of FIG. 4, the controller **550** monitors one or more electrical parameters of the system in order to control the economizer expansion device **77**. The one or more electrical parameters of the transport refrigeration system **10** may include one or more of output current of the generator **21**, output voltage of the generator **21**, current draw

of the compressor **20**, input voltage at the compressor **20**, current draw of one or more heat rejecting heat exchanger fans, input voltage at one or more heat rejecting heat exchanger fans, current draw of one or more evaporator fans, input voltage at one or more evaporator fans, current draw of one or more heaters (e.g., defrost coils) and input voltage at one or more heaters.

[0042] As shown in FIG. 4, the process begins at **400** with the transport refrigeration system **10** running in a non-economized mode. At **402**, controller **550** determines whether the transport refrigeration system **10** requires operation in an economized mode. If not, flow proceeds to **404** where the transport refrigeration system **10** continues operating in a non-economized mode. If at **402**, economized mode of operation is required, flow proceeds to **406** where an electrical parameter of one or more components is measured by controller **550**. It is understood that such measurements may be made using current and/or voltage sensors installed at various components to be monitored. At **408**, the controller **550** determines if the one or more electrical parameters exceeds a limit. The limit may be a current or voltage threshold for a component of the transport refrigeration system **10**. Block **408** may include detecting that a single electrical parameter exceeds a limit or multiple electrical parameters exceed respective limits. If at **408**, no electrical limit(s) are exceeded, then flow proceeds to **410** where the transport refrigeration system **10** may be operated in a full economized mode. Operating in full economized mode refers to operating the economizer expansion device **77** with no restrictions (e.g., a full opening and closing range of the economizer expansion device **77**). If at **408** one or more electrical limit(s) are exceeded, then flow proceeds to **412** where the transport refrigeration system **10** may be operated in a limited economized mode (e.g., a restricted opening and closing range of the economizer expansion device **77**). Operating in limited economized mode refers to operating the economizer expansion device **77** with restrictions such that the one or more electrical parameters does not exceed a limit.

[0043] One example of the operation of the transport refrigeration system **10** using the process of FIG. 4 includes monitoring current draw at compressor **20**. Modern generators **21** may be capable of providing excessive current to compressor **20**. If during economizer mode, the current draw at compressor **20** exceeds a limit, then the economizer expansion device **77** can be controlled (e.g., incrementally closed) to reduce refrigerant flow to the intermediate inlet port **167** to reduce current consumption by the compressor **20**.

[0044] FIG. 4 discloses a control method that may be used with multiple cargo compartments **112**, **114** and **116** each having a respective evaporator **40**, **50** and **60**. In alternate embodiments, control of the economizer expansion device **77** based on one or more electrical parameters may be employed in a transport refrigeration system **10** having a single cargo compartment and a single evaporator. Thus, control of the economizer expansion device **77** based on one or more electrical parameters is not limited to transport refrigeration systems having multiple cargo compartments, but may be applied to a single compartment.

[0045] Using the economizer expansion valve **77** to control compressor power has numerous advantages. Control of the economizer expansion valve **77** is much faster acting than typical suction throttling regimes for single stage compressor systems. A typical reaction time for a compressor suction modulation valve **201** is 30-45 seconds from open to close. A

typical reaction time for an economizer expansion device 77 (e.g., an electronically controlled stepper valve) is 6 seconds from open to close. Additionally, the refrigerant volume and mass in the economizer heat exchanger 148 is small, which tends to further increase reaction time and control by limiting stored refrigerant and subsequent energy.

[0046] Another benefit of the economized multi-temperature system is it allows for greater capacity from reduced pressure drop within the compartments and connecting tubing. Economized cycle capacity is driven by enthalpy and mass flow rate. To achieve the similar deep frozen capacity as a single stage system, enthalpy is increased in absence of mass flow rate. Typical mass flow rates of the economized scroll systems are 35-50% lower than single stage systems for same net capacity. Lower mass flow rate systems, such as that of FIG. 2, suffer less pressure drop effects from remote evaporator and line set losses. In addition, the economized cycle allows for smaller nominal low side piping diameter (e.g., 1½" vs. 7/8") throughout the length (e.g., 53') of the trailer offering a significant installed cost savings.

[0047] Another benefit of the economized multi-temperature system is that it allows for variable sub-cooling to remote evaporators in times of need. When distributing sub-cooled refrigerant through multi-temperature compartments, it is helpful to maintain a net positive sub-cooling to the remote evaporators to prevent pre-expansion before expansion device. At certain times, refrigerant sub-cooling can be altered from heat gain through the individual compartments in which the refrigerant is passed through. By allowing for very light partial flow through the economizer system at low loads or high power demands, the system maintains a positive sub-cooling environment to the remote evaporator expansion valves, thereby improving performance.

[0048] While the invention has been described in detail in connection with only a limited number of embodiments, it should be readily understood that the invention is not limited to such disclosed embodiments. Rather, the invention can be modified to incorporate any number of variations, alterations, substitutions or equivalent arrangements not heretofore described, but which are commensurate with the spirit and scope of the invention. Additionally, while various embodiments of the invention have been described, it is to be understood that aspects of the invention may include only some of the described embodiments. Accordingly, the invention is not to be seen as limited by the foregoing description, but is only limited by the scope of the appended claims.

1. A multi-compartment transport refrigeration system comprising:

- a compressor having a suction port, a discharge port and an intermediate inlet port located at an intermediate location along a compression path between the compressor suction port and the compressor discharge port;
- a heat rejecting heat exchanger downstream of the compressor discharge port;
- an economizer heat exchanger having a first refrigerant flow path and a second refrigerant flow path there-through;
- a first evaporator expansion device downstream of the first refrigerant flow path;
- a first evaporator having an inlet coupled to the first evaporator expansion device and an outlet coupled to a compressor inlet path, the compressor inlet path coupled to the compressor suction port, the first evaporator for cooling a first compartment of a container;

- a second evaporator expansion device downstream of the first refrigerant flow path;

- a second evaporator having an inlet coupled to the second evaporator expansion device and an outlet coupled to the compressor inlet path, the second evaporator for cooling a second compartment of the container; and
- an economizer expansion device coupled to the first refrigerant flow path, the economizer expansion device directing refrigerant from the first refrigerant flow path to the second refrigerant flow path, the second refrigerant flow path coupled to the intermediate inlet port.

2. The multi-compartment transport refrigeration system of claim 1 further comprising:

- a controller configured to control the economizer expansion device to regulate flow of refrigerant along the second refrigerant flow path to the intermediate inlet port.

3. The multi-compartment transport refrigeration system of claim 2 wherein:

- the controller is configured to control the economizer expansion device in response to an operating parameter of the refrigeration system.

4. The multi-compartment transport refrigeration system of claim 3 wherein:

- the controller is configured to control the economizer expansion device in response to superheat of the economizer heat exchanger.

5. The multi-compartment transport refrigeration system of claim 2 further comprising:

- an engine to provide power to the compressor;
- wherein the controller is configured to control the economizer expansion device in response to an operating parameter of the engine.

6. The multi-compartment transport refrigeration system of claim 2 wherein:

- the controller is configured to control the economizer expansion device in response to a refrigeration system loading event.

7. The multi-compartment transport refrigeration system of claim 2 wherein:

- the controller is configured to control the economizer expansion device in response to a pulsed control signal applied to one of the first evaporator expansion device and the second evaporator expansion device.

8. The multi-compartment transport refrigeration system of claim 7 wherein:

- the pulsed control signal is a pulse width modulation signal.

9. The multi-compartment transport refrigeration system of claim 2 wherein:

- the controller is configured to control the economizer expansion device in response to an electrical parameter of the refrigeration system.

10. The multi-compartment transport refrigeration system of claim 9 wherein:

- the electrical parameter of the refrigeration system includes one or more of output current of a generator, output voltage of a generator, current draw of the compressor, input voltage at the compressor, current draw of a heat rejecting heat exchanger fans, input voltage at the heat rejecting heat exchanger fan, current draw of an evaporator fan, input voltage at the evaporator fans, current draw of a heater and input voltage at the heater.

11. The multi-compartment transport refrigeration system of claim 9 wherein:

- control of the economizer expansion device in response to the electrical parameter of the refrigeration system includes:
- comparing the electrical parameter to a limit;
- operating the economizer expansion device in a full economized mode when the electrical parameter does not exceed the limit; and
- operating the economizer expansion device in a limited economized mode when the electrical parameter does exceed the limit.

12. A transport refrigeration system comprising:

- a compressor having a suction port, a discharge port and an intermediate inlet port located at an intermediate location along a compression path between the compressor suction port and the compressor discharge port;
- a heat rejecting heat exchanger downstream of the compressor discharge port;
- an economizer heat exchanger having a first refrigerant flow path and a second refrigerant flow path there-through;
- an evaporator expansion device downstream of the first refrigerant flow path;
- an evaporator having an inlet coupled to the evaporator expansion device and an outlet coupled to a compressor inlet path, the compressor inlet path coupled to the compressor suction port, the evaporator for cooling a compartment of a container;
- an economizer expansion device coupled to the first refrigerant flow path, the economizer expansion device directing refrigerant from the first refrigerant flow path to the

second refrigerant flow path, the second refrigerant flow path coupled to the intermediate inlet port; and

- a controller configured to control the economizer expansion device to regulate flow of refrigerant along the second refrigerant flow path to the intermediate inlet port, the controller configured to control the economizer expansion device in response to an electrical parameter of the refrigeration system.

13. The transport refrigeration system of claim 12 wherein:

- the electrical parameter of the refrigeration system includes one or more of output current of a generator, output voltage of a generator, current draw of the compressor, input voltage at the compressor, current draw of a heat rejecting heat exchanger fans, input voltage at the heat rejecting heat exchanger fan, current draw of an evaporator fan, input voltage at the evaporator fans, current draw of a heater and input voltage at the heater.

14. The transport refrigeration system of claim 12 wherein:

- control of the economizer expansion device in response to the electrical parameter of the refrigeration system includes:
- comparing the electrical parameter to a limit;
- operating the economizer expansion device in a full economized mode when the electrical parameter does not exceed the limit; and
- operating the economizer expansion device in a limited economized mode when the electrical parameter does exceed the limit.

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