SPATIAL CONTROL OF CONDITIONED GAS DELIVERY FOR TRANSPORT REFRIGERATION SYSTEM TO INCLUDE CARGO SPATIAL TEMPERATURE DISTRIBUTION, AND METHODS FOR SAME

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to U.S. Provisional Patent Application Serial No. 61/254,289 entitled "Spatial Control Of Conditioned Gas Delivery For Transport Refrigeration System To Include Cargo Spatial Temperature Distribution, And Methods For Same" filed on October 23, 2009. The content of this application is incorporated herein by reference in their entirety.

FIELD OF THE INVENTION

[0002] This invention relates generally to the field of transport refrigeration systems and methods of operating the same.

BACKGROUND OF THE INVENTION

[0003] To safely transport perishable items, the items must be maintained within a temperature range to reduce or prevent, depending on the items, spoilage, or conversely damage from freezing. A transport refrigeration unit is used to maintain proper temperatures within a transport cargo space. The transport refrigeration unit can be under the direction of a controller. The controller can regulate conditioned air delivery by the transport refrigeration unit to a container or the transport cargo space.

SUMMARY OF THE INVENTION

[0004] In view of the background, it is an aspect of the application to provide a transport refrigeration system, transport refrigeration unit, and methods of operating same for maintaining cargo quality by selectively controlling one or more transport refrigeration system components.

[0005] One embodiment according to the application can include a control module for a transport refrigeration system. The control module includes a controller for controlling the transport refrigeration system to operate at least one vent in a chute extending away from the supply port and/or return port of the transport refrigeration system.

[0006] One embodiment according to the application can include a control module for a transport refrigeration system. The control module includes a controller for controlling the transport refrigeration system to regulate air flow amount or flow direction from a plurality of vents in one or more air delivery chutes operatively coupled to a supply port and/or return port of the transport refrigeration system.

[0007] One embodiment according to the application can include a control module for a transport refrigeration system. The control module can regulate air flow amount or flow direction from one or more air delivery chutes operatively coupled to a supply port of the transport refrigeration system responsive to a network of sensors. The network of sensors can be in the container and/or the cargo. The network of sensors can be temperature sensors.

[0008] One embodiment according to the application can include a control module for a transport refrigeration system. The control module can include a controller for controlling the transport refrigeration system to regulate air flow amount or flow direction from one or more air delivery chutes operatively coupled to a supply port and/or return port of the transport refrigeration system responsive to a network of sensors. The network of sensors can be for a cargo characteristic and used to reduce differences in the cargo characteristic distributed throughout the container and/or the cargo.

[0009] In an aspect of the invention, a transport refrigeration unit includes a transport refrigeration unit operatively coupled to an enclosed volume. A conditioned portion of the transport refrigeration unit to include a supply port to output air to the enclosed volume at a supply temperature, a return port to return air from the enclosed volume to the transport refrigeration unit at a return temperature, and a passageway from the supply port to the enclosed volume to include a plurality of air flow volume controllers or air flow direction controllers.

[0010] In an aspect of the invention, a transport refrigeration unit for regulating the temperature of an enclosed volume can include a refrigeration module including a supply port to output air at a supply temperature; a return port to return air to the refrigeration module at a return temperature; at least one air plenum extending away from the refrigeration module, the plenum to include at least one configurable port to operate in a plurality of positions; and a controller coupled to regulate the operation of said at least one configurable port module responsive to a prescribed temperature.

[0011] In an aspect of the invention, an apparatus can include a supply air plenum extending rearward from the refrigeration unit toward the rear of the container that is arranged to receive supply air from said refrigeration unit, the supply air plenum to provide a continuous passageway through said container; a plurality of discharge ports positioned along a length of the plenum, said discharge ports to move between a first position to output air in a first direction and a second position to output the air in a second direction or in a different amount, and a plurality of temperature sensors positioned within the container to provide a temperature distribution in a spatial relationship to said plurality of discharge ports; and a controller to determine when to move at least one of the discharge ports between said first position and said second position responsive to temperature provided by the plurality of temperature sensors.

[0012] In an aspect of the invention, a method of operating a transport refrigeration unit can include receiving identifying information including location for a network of sensors, receiving identifying information including location and air flow settings for a plurality of discharge ports, the discharge ports to be operationally coupled to the transport refrigeration unit, receiving information related to a distributed cargo characteristic using the network of sensors, and modifying at least one airflow setting for the plurality of discharge ports responsive to the received information related to the distributed cargo characteristic.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] Novel features that are characteristic of exemplary embodiments of the invention are set forth with particularity in the claims. Embodiments of the invention itself may be best be understood, with respect to its organization and method of operation, with reference to the following description taken in connection with the accompanying drawings in which:

[0014] FIG. 1 is a diagram that shows an embodiment of a transport refrigeration system according to the application;

[0015] FIG. 2 is a diagram that shows an embodiment of a transport refrigeration system according to the application;

[0016] FIG. 3 is a diagram that shows an embodiment of a transport refrigeration system according to the application;

[0017] FIG. 4A is a diagram that shows an embodiment of a transport refrigeration system according to the application;

[0018] FIG. 4B is a diagram that shows an exemplary schematic cross-sectional view of a portion of FIG. 4A;

[0019] FIG. 5 is a diagram illustrating an embodiment of an air delivery system for a transport refrigeration system according to an embodiment of the application;

[0020] FIG. 6 is a diagram illustrating an exemplary embodiment of an air plenum or chute according to the application;

[0021] FIG. 7 is a diagram illustrating an exemplary embodiment of an air plenum or chute according to the application; and

[0022] FIG. 8 is a diagram illustrating an exemplary embodiment of an air plenum or chute according to the application.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0023] Reference will now be made in detail to exemplary embodiments of the application, examples of which are illustrated in the accompanying drawings. Whenever possible, the same reference numerals will be used throughout the drawings to refer to the same or like parts.

[0024] FIG. 1 is a diagram that shows an embodiment of a transport refrigeration system. As shown in FIG. 1, a transport refrigeration system 100 can include a transport refrigeration unit 10 coupled to an enclosed space within a container 12. The transport refrigeration system 100 may be of the type commonly employed on refrigerated trailers and maritime containers. As shown in FIG. 1, the transport refrigeration unit 10 is configured to maintain a prescribed thermal environment within the container 12 (*e.g.*, cargo in an enclosed volume).

[0025] In FIG. 1, the transport refrigeration unit 10 is connected at one end of the container 12. Alternatively, the transport refrigeration unit 10 can be coupled to a prescribed position on a side or more than one side of the container 12. In one embodiment, a plurality of transport refrigeration units can be coupled to a single container 12. Alternatively, a

single transport refrigeration unit 10 can be coupled to a plurality of containers 12 or multiple enclosed spaces within a single container. The transport refrigeration unit 10 can operate to induct air at a first temperature and to exhaust air at a second temperature. In one embodiment, the exhaust air from the transport refrigeration unit 10 will be warmer than the inducted air such that the transport refrigeration unit 10 is employed to warm the air in the container 12. In one embodiment, the exhaust air from the transport refrigeration unit 10 will be cooler than the inducted air such that the transport refrigeration unit 10 is employed to cool the air in the container 12. The transport refrigeration unit 10 can induct air from the container 12 having a return temperature Tr (*e.g.*, first temperature) and exhaust air to the container 12 having a supply temperature Ts (*e.g.*, second temperature).

[0026] In one embodiment, the transport refrigeration unit 10 can include one or more temperature sensors to continuously or repeatedly monitor the return temperature Tr and/or the supply temperature Ts. As shown in FIG. 1, a first temperature sensor 24 of the transport refrigeration unit 10 can provide the supply temperature Ts and a second temperature sensor 22 of the transport refrigeration unit 10 can provide the return temperature Tr to the transport refrigeration unit 10, respectively. Alternatively, the supply temperature Ts and the return temperature Tr can be determined using remote sensors.

[0027] A transport refrigeration system 100 can provide air with controlled temperature, humidity or/and species concentration into an enclosed chamber where cargo is stored such as in container 12. As known to one skilled in the art, the transport refrigeration system 100 (*e.g.*, controller 250) is capable of controlling a plurality of the environmental parameters or all the environmental parameters within corresponding ranges with a great deal of variety of cargos and under all types of ambient conditions.

[0028] FIG. 2 is a diagram that shows an embodiment of a transport refrigeration system. As shown in FIG. 2, a transport refrigeration system 200 can include a transport refrigeration unit 210 coupled to a container 212, which can be used with a trailer, an intermodal container, a train railcar, a ship or the like, used for the transportation or storage of goods requiring a temperature controlled environment, such as, for example foodstuffs and medicines (*e.g.*, perishable or frozen). The container 212 can include an enclosed volume 214 for the transport/storage of such goods. The enclosed volume 214 may be an enclosed space having an interior atmosphere isolated from the outside (*e.g.*, ambient atmosphere or conditions) of the container 212.

[0029] The transport refrigeration unit 210 is located so as to maintain the temperature of the enclosed volume 214 of the container 212 within a predefined temperature range. In one embodiment, the transport refrigeration unit 210 can include a compressor 218, a condenser heat exchanger unit 222, a condenser fan 224, an evaporation heat exchanger unit 226, an evaporation fan 228, and a controller 250. Alternatively, the condenser 222 can be implemented as a gas cooler.

[0030] The compressor 218 can be powered by single phase electric power, three phase electrical power, and/or a diesel engine and can, for example, operate at a constant speed. The compressor 218 may be a scroll compressor, a rotary compressor, a reciprocal compressor, or the like. The transport refrigeration system 200 requires electrical power from, and can be connected to a power supply unit (not shown) such as a standard commercial power service, an external power generation system (*e.g.*, shipboard), a generator (*e.g.*, diesel generator), or the like.

[0031] The condenser heat exchanger unit 222 can be operatively coupled to a discharge port of the compressor 218. The evaporator heat exchanger unit 226 can be operatively coupled to an input port of the compressor 218. An expansion valve 230 can be connected between an output of the condenser heat exchanger unit 222 and an input of the evaporator heat exchanger unit 226.

[0032] The condenser fan 224 can be positioned to direct an air stream onto the condenser heat exchanger unit 222. The air stream from the condenser fan 224 can allow heat to be removed from the coolant circulating within the condenser heat exchanger unit 222.

[0033] The evaporator fan 228 can be positioned to direct an air stream onto the evaporator heat exchanger unit 226. The evaporator fan 228 can be located and ducted so as to circulate the air contained within the enclosed volume 214 of the container 212. In one embodiment, the evaporator fan 230 can direct the stream of air across the surface of the evaporator heat exchanger unit 226. Heat can thereby be removed from the air, and the reduced temperature air can be circulated within the enclosed volume 214 of the container 212 to lower the temperature of the enclosed volume 214.

[0034] The controller 250 such as, for example, a MicroLink.TM 2i controller available from Carrier Corporation of Syracuse, New York, USA, can be electrically connected to the

compressor 218, the condenser fan 224, and/or the evaporator fan 228. The controller 250 can be configured to operate the transport refrigeration unit 210 to maintain a predetermined environment (*e.g.*, thermal environment) within the enclosed volume 214 of the container 212. The controller 250 can maintain the predetermined environment by selectively controlling operations of the condenser fan 224, and/or the evaporator fan 228 to operate at a low speed or a high speed. For example, if increased cooling of the enclosed volume 214 is required, the controller 250 can increase electrical power to the compressor 218, the condenser fan 224, and the evaporator fan 228. In one embodiment, an economy mode of operation of the transport refrigeration unit 210 can be controlled by the controller 250. In another embodiment, variable speeds of components of the transport refrigeration unit 210 can be adjusted by the controller 250. In another embodiment, a full cooling mode for components of the transport refrigeration unit 210 can be controlled by the controller 250. In one embodiment, the electronic controller 250 can adjust a flow of coolant supplied to the compressor 218.

[0035] FIG. 3 is a diagram that shows an embodiment of a transport refrigeration system. As shown in FIG. 3, transport refrigeration system 300 can include a transport refrigeration unit 310 to couple to an enclosed space 314 within a container 312. As described herein, the transport refrigeration systems, transport refrigeration modules, components and methods for controlling the same can operate in a cooling mode and a heating mode depending at least in part upon the temperature of the conditioned space and the ambient temperature of the environment outside the enclosed space 314. Air that is cooled or heated by the transport refrigeration system 300 can be drawn by a fan (*e.g.*, blower assembly), conditioned and discharged into the enclosed space 314.

[0036] In one embodiment, the transport refrigeration unit 310 can be considered to have a first refrigerated (*e.g.*, conditioned) portion for operative coupling to the enclosed space 314 and a second ambient (*e.g.*, not conditioned) portion that is insulated from the enclosed space 314 (and the first refrigerated portion). For example, an evaporator 326 and evaporator fan 328 can be in the first refrigerated portion and a condenser 322 and a condenser fan 324 can be in the second ambient portion of the transport refrigeration unit 310. A first wall 340 (*e.g.*, physical and/or thermal barrier) can be positioned between the first refrigerated portion and the second ambient portion.

[0037] As shown in FIGS. 3-4B, the transport refrigeration unit 310 is in communication with the enclosed space 314 via a first opening 350 and a second opening 355 to maintain the enclosed volume 314 at predetermined conditions (*e.g.*, temperature, humidity, etc.) during transportation and/or storage in order to preserve the quality of the cargo. The first opening 350 and the second opening 355 can be in a first compartment wall 345 configured to face or be operatively coupled to the enclosed space 314. A compartment 330 can enclose the transport refrigeration unit 310. As shown in FIG. 3, the compartment 330 is shown as a rectangular box; however, the exterior shape of the compartment 330 can vary as known to one skilled in the art. Generally, the transport refrigeration unit 310 is operable in a refrigeration mode and includes one or more refrigeration components (not entirely shown), such as an evaporator 336, one or more compressors, a condenser, one or more fans, a receiver, and one or more expansion valves to route refrigerant through the transport refrigeration unit 310. Such arrangements are known in the art.

[0038] In one embodiment, vents 390 are controlled based on relative position within the enclosed space 314, based on relative position along plenums or chutes 370, distributed characteristic determined by a plurality of sensors 380 in the container 312, and/or based on the local temperature of the cargo (*e.g.*, correspondingly positioned in the enclosed space 314) as determined by a network of temperature sensors spatially distributed throughout the cargo and/or the container 312. In one embodiment, a distributed characteristic can include humidity, temperature, presence of gases, chemicals, and/or scheduling (*e.g.*, delivery)

[0039] The supply air can be released from the vents 390 that are controlled based on relative position in the enclosed space 314. In one embodiment, the vents 390 can be fixed sized openings in the chutes 370 with structures (*e.g.*, mechanical) controlling an amount of air flow released therefrom or variable sized openings regulated or controlled by the controller 350' (not shown). In one embodiment, a direction of air flow output by the vents output 390 can be controlled (*e.g.*, 0° – 360° in a horizontal plane, 0° – 90° in a vertical plane, or controlled in 3-D space).

[0040] According to embodiments of the application, one or more chutes 370 extend away from the second opening 355 to deliver supply air in a controlled fashion to the enclosed space 314. In one embodiment, the chutes 370 can extend an entire length of the trailer or the container 312. In one embodiment, the chutes 370 can extend less than the full length including but not limited to, extending up to 10%, 25%, 50%, 75%, 90%, etc. of the

length of the trailer or the container 312. The chutes 370 are operatively coupled to receive the supply air from the transport refrigeration unit 310 (*e.g.*, from the second opening 355). The chutes 370 can release or controllably deliver the supply air to the enclosed space 314 using a plurality of controllable vents 390 in the chutes 370.

[0041] In one embodiment, the chutes 370 can include a single chute 370a extending from the second opening 355 along the top of the container 312 spaced from sides of the container 312. The chute 370a can extend down the center top of the container 312 or the enclosed space 314. Alternatively, the chutes 370 can comprise a plurality of chutes 370a, 370b, ... 370n extending along the top of the container 312 spaced from the sides of the container 312. Further, the chutes 370a, 370b, ... 370n can join together or split apart and separate along the distance from the second opening 355. Thus, in one embodiment, a single chute 370a could extend from the second opening 355 before separating into a plurality of chutes 370. In one embodiment, when chutes 370 recombine/join or separate, an air control device such as but not limited to a baffle or valve can be positioned at such junctures to selectively determine a ratio of air entering or leaving each of the plurality of sub-chutes before separation or conjuncture.

[0042] In one embodiment, chutes 370 can include a single chute 370a' extending across a top of the container 312 (*e.g.*, continuously from side to side). The chute 370a' can extend away from the second opening 355 partially or completely to a back of the container 312. In one embodiment, the chute 370a' can also include drop portions 378 that extend vertically from a top surface toward the floor of the container 312. In one embodiment, the drop portions 378 extend adjacent or near one or both sides of the container 312. In one embodiment, the drop portions 378 extend spaced across part of or the entire top of the container 312. The drop portions 378 of the chutes 370 can extend at least 10%, 25%, 50%, or more than 50% toward the floor of the container 312. Further, the chute 370a' can subdivide as it extends away from the second opening 355.

[0043] In one embodiment, the chutes 370 can include chutes 370a" comprising at least one chute extending along a side surface of the container 312. In one embodiment, the chutes 370a", 370b" comprise two chutes where one extends away from the second opening 355 along respectively the top and each opposing side of the container 312 (or the enclosed space 314). Alternatively, the chutes 370a", 370b',...370n' can extend along sidewalls of the

container 312 but vertically spaced from the top. The chutes 370a", 370b",...370n" can each subdivide and/or recombine along a length extending away from the second opening 355.

[0044] In exemplary embodiments, the second opening 355 can include a number of spaced sub-openings 355a, 355b, ..., 355n so that each of the plurality of chutes 370 (*e.g.*, 370a, 370b, ... 370n) can extend from a corresponding second sub-opening 355a, 355b, ..., 355n.

[0045] In one embodiment, the chutes 370 can include the two side walls and the roof as being two layer structures where supply air flows completely through and between the two layer structures of the side walls and roof and then vents 390 can be positioned as desired (*e.g.*, anywhere along the roof 321, or sidewalls 322, 323). In such an embodiment, the container 312 or enclosed space 314 may lose some overall size (*e.g.*, 1-12 inches (3-30 cm) on the top and lose 1-12 inches (2-30 cm) on the sides) however, the capability for air flow control to provide the supply air anywhere within the enclosed space 314 would be added (*e.g.*, without ducts or chutes 370). In such an embodiment, the vents 390 can include controllable holes that can be open, partially open, directional, or closed.

[0046] In one embodiment, the chutes 370 can include flexible ducts that can be pre-installed or maneuvered into position based upon the cargo in the container 312.

[0047] In one embodiment, the configuration of the chutes 370 can be pre-determined or optimized computer designed configuration(s) that can (*e.g.*, remove 90 degree corners and subdivide/recombine) controllably provide or direct supply air into each area/position in the container 312. Generally any potential configuration of the chutes 370 from the second opening 355 (or sub-openings 355a, 355b, ..., 355n) to deliver supply air can be considered. Equivalent methodologies and/or apparatus are known to one of ordinary skill in the art to provide passageways for supply air like chutes 370 or means for air delivery to be delivered to an enclosed space 314 of a refrigeration transport system; and all equivalent methodologies and/or chutes are considered to fall within the scope of embodiments of the application.

[0048] In one embodiment, a network of sensors 380 sufficient to determine localized variations in at least one characteristic (*e.g.*, temperature, presence of gas, humidity, etc.) in the enclosed space 314 or cargo (*e.g.*, distributed characteristic sensing means) is operatively coupled to the transport refrigeration system or controller 350'. In one embodiment, a

network of sensors 380 sufficient to determine localized temperature variations in cargo temperature is supplied and/or positioned among the cargo, the enclosed space 314 and/or the container 312. The sensors 380 can be various temperature sensors as known to one skilled in the art that are operatively coupled to the controller 350' (*e.g.*, wired or wireless). In one embodiment, the sensors 380 can include RFID capabilities. The network of sensors 380 can be a 2D grid at a prescribed height between the bottom and top of the enclosed space 314. In one embodiment, the network of sensors 380 can be a 3D grid disposed throughout the enclosed space 314. For example, the sensors 380 can be positioned separated by at least 1', 2', 4', 6', 8', or the like in the 2D or 3D configuration. However, embodiments of the application are not intended to be so limited. For example, the network of sensors 380 can arbitrarily or randomly disposed in the enclosed space 314, the container 312, or the cargo, and then the corresponding data can be processed, interpolated, or estimated to provide the localized temperature distributions in the transport refrigeration system 300. The interpolated data can result in a grid 2D or 3D grids of temperature data or the distributed (cargo) characteristic.

[0049] In one embodiment, a network of sensors 380 sufficient to determine localized temperature variations can be stationary. Such stationary sensors 380 can be mounted on the sides 322, 323 (ceilings, support structures, ducts, fans etc.) of the container 312, the shipping materials supporting or containing the cargo (*e.g.*, pallets) or disposed throughout the cargo itself. In one embodiment, cargo can be individually packaged, packaged as a group (*e.g.*, boxed or bagged) or packaged as a set of groups (*e.g.*, for loading). In such exemplary shipping configurations, the sensors 380 can be disposed per individual item (*e.g.*, every 1, 5, 10, 100, or 1000 items), 1 or more sensor 380 per group of individual items (*e.g.*, box), 1 or more sensor 380 per loadable unit to be shipped or loaded in the container 312 or the like. In one embodiment, the sensors 380 are positioned near each corner of each loadable unit. According to embodiments of the application, the networks of sensors 380 can operate to provide localized differences in temperature to enable the control of vents 390 in combination with chutes 370 to reduce or eliminate temperature fluctuations that can damage or lead to damage of cargo in the enclosed space 314.

[0050] In one embodiment, a network of sensors 380 sufficient to determine localized temperature variations can be movable or movably configured within the container 312. For example, the network of sensors 380 can be controllable mounted on a track or system of

wires such that individual sensors 380 can be moved to obtain more granularity for localized temperatures or be moved toward temperature sensitive cargo portions. Alternatively, the network of sensors 380 can be moved toward larger temperature differences. In one embodiment, the exemplary moveable network of sensors 380 can be self-powered or movable by outside force applied by one or more controllable mechanisms. In one embodiment, various arrangements of movable sensors 380 or networks of movable sensors 380 can be controlled by the controller 350'. In one embodiment, arrangements of movable sensors 380 can be controllable moved by the controller 350' from first prescribed configuration to a second prescribed configuration different from first configuration. For example, differences implemented by the second configuration can include but are not limited to the second configuration increasing a granularity of localized information (*e.g.*, temperature) in one area relative to the first configuration, decreasing a granularity, replacing defective sensors, reducing active sensors to save power, massing sensors relative to type of cargo (*e.g.*, sensitivity to temperature), or attempting to resolve anomalies in one or more sensor readings.

[0051] The network of sensors 380 can determine localized temperatures (*e.g.*, 2D grids or 3D grids) to encompass the cargo in the enclosed space 314. In one embodiment, the network of sensors 380 can be used to correlate sensed conditions (*e.g.*, temperatures) to the plurality of vents 390. For example, one grid section, or a plurality of grid sections determined using the sensors 380 can correspond to a vent 390a, 390b, ...390n of the vents 390 of the chutes 370. Alternatively, one sensor, two sensors, three or more sensors 380 can correspond to a vent 390a, 390b,...390n of the vents 390. In one embodiment, a plurality of vents 390a, 390b,...390n can correspond to a single sensor 380 or grid section as defined by the sensors 380. Accordingly, a localized cargo temperature difference (*e.g.*, in one grid section) can be determined by the controller 350' and at least one corresponding vent 390a, 390b,...390n can be adjusted (*e.g.*, size increase or damper position relatively increased/decreased) to control for and reduce (or eliminate) the localized temperature difference. The localized temperature difference can be below or above a desired temperature threshold, or the localized temperature difference can be below or above at least one neighboring temperature.

[0052] In one embodiment, the vents 390 can adjust the flow of air. In one embodiment, the vents 390 can adjust the direction of air flow. For example, the vent can include a nozzle

that can be moved in a prescribed x/y direction, around a 360 degree arc or the like. In one embodiment, the vents 390 can adjust the flow and/or direction of air. As known by those skilled in the art, vent sizes can be increased or decreased by alternative mechanical apparatuses. In selected configurations of the chutes 370 and/or vents 390, static pressure losses can increase so that increased air flow to/in the chutes 370 may be desired based on respective applications thereof.

[0053] According to embodiments of the application, the vents 390 are intended to control air flow out of (or into) the chutes 370 at its location. Thus, the vents 390 are intended to be air flow regulators or operate to meter the air flow. In one embodiment, the vents 390 include a mechanical device that changes position or shape to controllably moderate the air flow. For example, the vents 390 can include louvers or a valve such as a butterfly valve or a solenoid valve. In one embodiment, the vents 390 can include a flat disc with an off-center hole and a local actuator to reciprocally slide the disc over corresponding vent(s) 390. Alternatively, the vents 390 can operate to regulate air flow amount or direction. In one embodiment, the vents 390 can include a shape memory alloy capable of changing its configuration or size to moderate air flow there through. Equivalent methodologies and/or apparatus are known to one of ordinary skill in the art to regulate or provide controlled air flow volume and/or direction for supply air to be delivered (*e.g.*, air flow direction means or air flow volume means) to an enclosed space 314 of a refrigeration transport system from the vents 390; and all equivalent methodologies and/or vents are consider to fall within the scope of embodiments of the application.

[0054] In one example, the container 312 cargo can include stackable cargo depending on the product. Loaded cargo can be provided front to back in the container with return air flowing under the cargo. For example, all the return flow can go from on top of the cargo (*e.g.*, below chutes 370), through gaps or a little bit of room can be left in-between loaded cargo and on sides of stacked cargo, and back along the bottom 324 (*e.g.*, thru the pallet spacing).

[0055] Embodiments of transport refrigeration units and methods for using the same according to the application have been described a generally a static configuration of chutes 370, sensor 380, and/or vents 390. However, embodiments are not intended to be so limited. For example, sensor networks, vents or the like can to include reconfigurable networks. In one embodiment, reconfigurable networks includes transport refrigeration systems where

sensors or vents are getting on the network and/or off the network intermittently, repeatedly, periodically, aperiodically or responsive to an operator action. In one embodiment, reconfigurable networks include one or more chutes 370 mounted on rails to move about (*e.g.*, side-to-side) the container. In one embodiment, reconfigurable networks includes transport refrigeration systems where sensors or vents that are changing such as but not limited to changing locations intermittently, repeatedly, periodically, aperiodically or responsive to an operator action.

[0056] In one embodiment, two separate sensors are compared and a first sensor transmits a higher local temperature than a second sensor, and the controller opens a vent 390a closer to the first sensor and closes a vent 390b closer to the second sensor. Alternatively, the controller can redirect air from vent 390b toward the first sensor and/or away from the second sensor.

[0057] In one embodiment, a controller 350' can be enabled (*e.g.*, sensor ready) and receive a plurality of temperature readings from corresponding first sensors 380x in the cargo. The controller 350' is also connected to actuate an unknown plurality of vents 390x in the cargo area. For example, the controller 350' can be connected using a standard wireless connection to the vents 390x and sensors 380x. The sensors 380x can transmit a temperature and their location. Alternatively, the location of the sensors 380x can be determined by the controller 350' when the sensors 380x transmit their readings using signal strength (*e.g.*, triangulation such as point-to-point or broadcast) and the controller 350', one designated sensor or a designated device or transceiver in the container or nearby. The sensor ready controller 350' could then sequentially open a single one of the vents 390x to determine a location of each individual vent of the vents 390x (*e.g.*, by reported temperature changes of the sensors 380x when a single vent is open). After receiving a configuration of sensor 380x and determining a configuration of vents 390x, the controller 350' can determine localized temperature differences of a cargo and operate to reduce a temperature difference distributed in the cargo by distributing/modifying air flow (or direction) through the vents 390x.

[0058] In one embodiment, a controller 350' can be enabled (*e.g.*, sensor ready) and receive a plurality of temperature readings and determine locations from corresponding sensors 380y in the cargo and receive a plurality of airflow settings and determine locations (*e.g.*, transmission signal strength) from corresponding vents 390y in the cargo area.

[0059] Embodiments according to the application were described using exemplary chutes 370 coupled to a second opening 355 or the supply air from the transport refrigeration system. However, embodiments are not intended to be so limited; for example, exemplary chutes (*e.g.*, chutes 370) can be operatively coupled to the return air or the first opening 350 of the transport refrigeration system (*e.g.*, instead of or in addition to the air supply/second opening 355). In one embodiment, air flow returned to the return port can be controlled to reduce difference in localized temperatures or the like. For example, more return air can be locally pulled from a portion of the enclosed space 314, which would increase supply air to that portion to control localized temperature. In loaded cargo, the return air can approach the return port or first opening 350 by coming in under the cargo or pallets (*e.g.*, where the forks lifts slide before lifting the pallets). In one embodiment, that area under the pallets or the floor, or bottom 324 of the container 312 can be flat; however, alternate configurations can provide additional grading to provide channels, grooves, passages or chutes where the return air flow can be regulated (*e.g.*, without obstructing the fork lifts).

[0060] According to embodiments of the application, the networks of sensors can operate to provide localized differences in temperature to enable the control of vents in combination with chutes to reduce or eliminate temperature fluctuations or to reduce power consumption of transport refrigeration systems.

[0061] Embodiments according to the application were described using a single second opening 355; however, embodiments are not intended to be so limited. For example, two second openings, three or more second openings can be provided according to embodiments of the application. In one embodiment, the second opening 355 can be equal or greater in number to a number of chutes 370.

[0062] Embodiments of transport refrigeration systems or units, air delivery chutes in containers, containers and methods for using same according to the application can maintain a prescribed thermal environment for a cargo in a container regardless of weather conditions, environment breaches (*e.g.*, door openings), various initial temperature distributions of cargo, various types of cargo, various heat transfer characteristics of cargo, or enclosed spaces 314, and/or various temperature regulation requirements of cargo.

[0063] Embodiments of transport refrigeration systems or units, air delivery chutes (*e.g.*, in containers), containers and methods for using same according to the application can

effectively operate with various cargo types including, but not limited to air blocking cargo (*e.g.,* shrink wrapped, frozen), air passing cargo (*e.g.,* stacked cargo with passages in between each), air diffusing cargos, etc.

[0064] Exemplary embodiments of chutes 370 were described using unchanging cross-sections. However, embodiments according to the application are not intended to be so limited. For example, various changing cross-sections including but not limited to tapered, non-linear, stepped may be used. Further, various different cross-section shapes including but not limited to circular, rectangular, square, triangular of the vent 390 can be used.

[0065] The container 12 illustrated in FIG. 1 may be towed by a semi-truck for road transport. However, those having ordinary skill in the art will appreciate that exemplary containers according to embodiments of the application is not limited to such trailers and may encompass, by way of example only and not by way of limitation, intermodal containers, trailers adapted for piggy-back use, railroad cars, and container bodies contemplated for land and sea service.

[0066] Components of the transport refrigeration unit (*e.g.,* motors, fans, sensors), as known to one skilled in the art, can communicate with a controller (*e.g.,* transport refrigeration unit 10) through wire or wireless communications. For example, wireless communications can include one or more radio transceivers such as one or more of 802.11 radio transceiver, Bluetooth radio transceiver, GSM/GPS radio transceiver or WIMAX (802.16) radio transceiver. Information collected by sensor and components can be used as input parameters for a controller to control various components in transport refrigeration systems. In one embodiment, sensors may monitor additional criteria such as humidity, species concentration or the like in the container.

[0067] Also, it is to be understood that the phraseology and terminology used herein is for the purpose of description and should not be regarded as limiting. The use of "including," "comprising," or "having" and variations thereof herein is meant to encompass the items listed thereafter and equivalents thereof as well as additional items. Unless specified or limited otherwise, the terms "mounted," "connected," "supported," and "coupled" and variations thereof are used broadly and encompass both direct and indirect mountings, connections, supports, and couplings. Further, "connected" and "coupled" are not restricted to physical or mechanical connections or couplings.

[0068] While the present invention has been described with reference to a number of specific embodiments, it will be understood that the true spirit and scope of the invention should be determined only with respect to claims that can be supported by the present specification. Further, while in numerous cases herein wherein systems and apparatuses and methods are described as having a certain number of elements it will be understood that such systems, apparatuses and methods can be practiced with fewer than the mentioned certain number of elements. Also, while a number of particular embodiments have been set forth, it will be understood that features and aspects that have been described with reference to each particular embodiment can be used with each remaining particularly set forth embodiment. For example, aspects or features described with respect to embodiments directed to FIGS. 6-7 can be used with embodiments directed to FIG. 5.

WE CLAIM:

1. A transport refrigeration unit for regulating temperature of an enclosed volume, the transport refrigeration unit comprising:

a refrigeration module including:

a supply port to output air at a supply temperature;

a return port to return air to the refrigeration module at a return temperature;

at least one plenum extending away from the refrigeration module, the at least one plenum in fluid communication with the supply port and including a plurality of ports opening into the enclosed volume, each port configurable to operate in a plurality of positions;

a plurality of temperature sensor units spatially distributed throughout the enclosed volume to provide a local cargo temperature distribution within the enclosed volume; and

a controller coupled to regulate operations of said plurality of configurable ports, said controller arranged to operate said plurality of configurable ports responsive to said local cargo temperature distribution.

2. The transport refrigeration unit of claim 1 comprising a network of cargo temperature sensor units, said controller to determine localized temperatures or temperatures for grids from said plurality of temperature sensor units, said controller to operate said plurality of configurable ports to control a flow therethrough or to control a direction of the flow therethrough responsive to readings of the plurality of temperature sensor units.

3. The transport refrigeration unit of claim 2, each temperature sensor unit is wirelessly connected or has a wired connection to the refrigeration module, wherein the plurality of temperature sensor units and the plurality of configurable ports have a prescribed relationship.

4. The transport refrigeration unit of claim 1, said controller to selectively operate said at least one plenum in a first mode of operation or in a second mode of operation responsive to said cargo temperature distribution or responsive to said supply temperature and said return temperature.

5. The transport refrigeration unit of claim 4, wherein the first mode of operation and the second mode of operation have different positions for at least two of said plurality of different configurable ports or the first mode of operation and the second mode of operation provide different spatial distributions of air leaving the at least one plenum.

6. The transport refrigeration unit of claim 1, wherein said plurality of configurable ports are configured to operate in a plurality of positions between a first closed position and a second open position, each configurable port coupled to an actuator to reciprocally move between said plurality of positions, said actuator wirelessly connected or has a wired connection to the controller.

7. The transport refrigeration unit of claim 1, said refrigeration module including:

a compressor having a discharge port and an input port;

a heat rejection heat exchanger unit operatively coupled to said discharge port;

an heat absorption heat exchanger unit operatively coupled to said input port;

a first fan disposed proximate to said heat rejection heat exchanger unit; and

a second fan disposed proximate to said heat rejection heat exchanger unit, said controller to regulate said compressor, said first fan, and said second fan.

8. The transport refrigeration unit of claim 1, said controller to operate said refrigeration module responsive to a humidity, cargo respiration, presence of gases, presence of chemicals, schedule, or species concentration of the enclosed volume or ambient conditions outside the enclosed volume.

9. The transport refrigeration unit of claim 1, comprising a container coupled to the refrigeration module, said container to include a first plenum extending along a surface of the container between a front end adjacent to the refrigeration module and an opposite end, said surface to be at least one of a top surface and side surfaces of the container or to include a second plenum having a U-shape to extend along the top surface of the container and partially down the side surfaces between the front end adjacent to the refrigeration module and the opposite end.

10. The transport refrigeration unit of claim 1, where said at least one plenum has a prescribed configuration to include at least a split into a plurality of first sub-plenums, joinder

between at least two sub-plenums, or a plurality of second sub-plenums coupled to corresponding portions of the supply port.

11. The transport refrigeration unit of claim 1 for delivering conditioned air to a container defining the enclosed volume and comprising;

a supply air plenum extending rearward from the transport refrigeration unit toward the rear of the container that is arranged to receive supply air from the supply port of said transport refrigeration unit, the supply air plenum to provide a continuous passageway through said container;

a plurality of discharge ports positioned along a length of the supply air plenum, the plurality of discharge ports to move between a first position to output air in a first direction and a second position to output the air in a second direction or in a different amount, and

a plurality of temperature sensors positioned within the container to provide a temperature distribution in a spatial relationship to said plurality of discharge ports; and

a controller configured to determine when to move at least one of the plurality of discharge ports between the first position and the second position responsive to temperature provided by the plurality of temperature sensors.

12. The apparatus of claim 11, further comprising:

a second supply air plenum extending rearward from the transport refrigeration unit toward the rear of the container along one sidewall of the container arranged to receive the supply air from said transport refrigeration unit, the second supply air plenum being spaced apart from an adjacent first sidewall of said container;

a second plurality of discharge ports positioned along the second supply air plenum, said second plurality of discharge ports to move between the first position capable of allowing air to pass therethrough and the second position to block air from passing therethrough;

a third supply air plenum extending rearward from the transport refrigeration unit toward the rear of the container along an opposite sidewall of the container arranged to receive the supply air from said transport refrigeration unit, the third supply air plenum being spaced apart from an adjacent second side wall of said container;

a third plurality of discharge ports positioned along the third supply air plenum, said third plurality of discharge ports to move between the first position capable of allowing air to pass therethrough and the second position to block air from passing therethrough.

13. The apparatus of claim 11, wherein the supply air plenum has a U-shape.

14. The apparatus of claim 11, wherein the container is separated into modular units having sidewalls extending up from a bottom surface over halfway to a top surface; each of said modular units corresponding to at least one discharge port; said each of said modular units to include at least one temperature sensor.

15. A method of operating a transport refrigeration system, comprising:

receiving identifying information including location for a plurality of spatially distributed temperature sensors that provide a cargo temperature distribution;

receiving identifying information including location and air flow settings for a plurality of discharge ports in the enclosed volume, the discharge ports to be operationally coupled to a transport refrigeration unit;

receiving information related to a distributed cargo characteristic using the plurality of sensors; and

modifying at least one airflow setting for the discharge ports responsive to the received information related to the distributed cargo temperature.