Title: METHOD FOR OPERATING TRANSPORT REFRIGERATION UNIT WITH REMOTE EVAPORATOR

Abstract: A transport refrigeration unit for cooling the interior of a cargo box having multiple cargo compartments includes a refrigerant compressor, a main evaporator associated with a first compartment of the trailer and a remote evaporator associated with a second compartment of the cargo box. During loading of product into at least one compartment, a controller determines the degree of superheat (CSS) in the refrigerant, compares the degree of suction superheat (CSS) to a lower limit for the degree of superheat (LSS), and continues operation of the refrigerant unit in a refrigeration mode if the degree of suction superheat (CSS) is greater than the lower limit for the degree of superheat (LSS); or terminates operation of the refrigerant unit in the refrigeration mode if the degree of suction superheat (CSS) is not greater than the lower limit for the degree of superheat (LSS) and initiates a defrost of at least one of the evaporators.
METHOD FOR OPERATING TRANSPORT REFRIGERATION UNIT WITH REMOTE EVAPORATOR

Field of the Invention

[0001] This invention relates generally to transport refrigeration and, more specifically, to facilitating defrost of the heat exchanger coil of a remote evaporator during the period when product is being loaded into a compartment cargo box of a truck trailer equipped with a refrigeration unit including multiple evaporators.

Background of the Invention

[0002] The refrigerated cargo box of a truck trailer requires a refrigeration unit for maintaining a desired temperature environment within the interior volume of the cargo box. 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 cargo boxes are compartmentalized into two or more separate cargo compartments each of which will typically have a door that opens directly to the exterior of the trailer. The cargo box 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.

[0003] Conventional transport refrigeration units used in connection with compartmentalized refrigerated cargo boxes 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 includes a housing mountable to the exterior of the front wall of the cargo box of the truck trailer with the main evaporator disposed on the interior of the front wall such that the air or gas/air mixture or other gas within the interior volume of the forward most container may be circulated over the evaporator coil by means of an evaporator fan associated with the evaporator coil. The refrigeration unit may also be equipped with an economizer incorporated into the refrigerant circuit, if desired. The refrigeration unit must have sufficient refrigeration capacity to maintain the perishable
product stored within the various compartments of the cargo box at the particular desired
compartment temperatures over a wide range of outdoor ambient temperatures and load
conditions.

In addition to the main afore-mentioned 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 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 in operation
with a system controller so that each remote evaporator may to 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. For example, U.S. Patent No. 5,065,587 discloses a refrigeration system for a
compartmentalized truck trailer having a forward compartment and a rear remote
compartment.

Product to be shipped is loaded into the cargo box of the truck trailer
through one or more doors. In a compartmentalized cargo box, each of the respective
cargo compartments generally has one or more associated doors through which product
may be loaded directly into the various compartments from externally of the truck trailer.
When loading product into a compartment of the truck trailer, it is customary to leave the
door or doors to the compartment open to facilitate the loading operation. With the door
or doors open, relatively warmer moisture bearing ambient air from externally of the
truck trailer may enter the compartment, such as, for example, when fresh fruits and
vegetables are loaded direct from the field. Simultaneously, relatively colder refrigerated
air may pass out of the compartment. Additionally, when product is loaded into the
container "hot", that is at a temperature above the desired product storage temperature,
such as for example directly from the field at ambient outdoor temperature, a substantial
refrigeration load is imposed upon the transport refrigeration unit in pulling the
temperature of the newly loaded product down from ambient outdoor temperature to the
desired product storage temperature. The net effect being to raise the temperature of and
to add moisture to the air resident within the compartment, particularly in regions with
warm and humid ambient conditions.

[0006] In the compartmentalized transport refrigeration system disclosed in the
aforementioned U.S. Patent No. 5,065,587, the remote evaporator is automatically shut
down whenever the door to the rear compartment is open. However, many operators
prefer to run the transport refrigeration unit during the product loading operation to
counter the impact of the infiltration of relatively warmer ambient air and the added heat
load associated with the product, and to reduce the time required to pull down the cargo
box when the loading operation has been completed. As a result of the increased
moisture within the interior volume of the compartment or compartments being loaded,
frost will build-up on the evaporator heat exchanger coil disposed within the
compartment or compartments being loaded and will do so more quickly than under
normal steady-state operating conditions. As frost builds up on the evaporator heat
exchanger coil, the cooling capacity and the pull down of the refrigeration unit decreases
and air flow through the affected evaporator decreases.

[0007] During the product loading process, it is conventional practice for the
operator to manually initiate an evaporator coil defrost cycle whenever the operator
deems appropriate. However, some operators may forget to manually initiate the defrost
cycle until the evaporator heat exchanger coil has become excessively burdened with
frost build up and the refrigeration capacity and performance of the evaporator heat
exchanger coil has substantially deteriorated. Accordingly, it would be desirable to
provide a transport refrigeration unit wherein a defrost cycle is automatically initiated
during the product loading procedure whenever the refrigeration performance of the
refrigeration unit has deteriorated below an acceptable level.

Summary of the Invention

[0008] The operation of a transport refrigeration unit is controlled during loading
of product into a cargo compartment equipped with a remote evaporator to automatically
defrost the remote evaporator when a selected parameter indicative of the performance of
the refrigeration unit has transgressed a limit threshold indicative of deteriorating performance.

[0009] A method is provided for operating a transport refrigeration unit during loading of product into a cargo box, for example in an embodiment a truck trailer, having at least a first and a second compartment. The refrigeration unit has a refrigerant flow circuit including a refrigerant compressor having a suction inlet, a main evaporator disposed in a first compartment and a remote evaporator disposed in a second compartment, connected in refrigerant flow communication. The method includes the steps of: determining a degree of superheat (CSS) in the refrigerant at the suction inlet to the compressor, comparing the degree of suction superheat (CSS) to a lower limit for the degree of superheat (LSS) at the suction inlet to the compressor, continuing operation of the refrigerant unit in a refrigeration mode if the degree of suction superheat (CSS) is greater than the lower limit for the degree of superheat (LSS) and terminating operation of the refrigerant unit in the refrigeration mode if the degree of suction superheat (CSS) is not greater than the lower limit for the degree of superheat (LSS) and initiating a defrost of the remote evaporator.

[0010] In an embodiment, the step of determining a degree of superheat (CSS) in the refrigerant at the suction inlet to the compressor comprises the steps of sensing a refrigerant temperature (CST) indicative of the refrigerant temperature at the suction inlet to the compressor, sensing a refrigerant pressure (CSP) indicative of the refrigerant pressure at the suction inlet to the compressor, determining a suction saturation temperature (SST) based upon the sensed refrigerant pressure (CSP) indicative of the refrigerant pressure at the suction inlet to the compressor, and subtracting the suction saturation temperature (SST) from the sensed refrigerant temperature (CST) indicative of the refrigerant temperature at the suction inlet to the compressor.

[0011] In an embodiment, the step of initiating a defrost of the main evaporator if product is being loaded into the first compartment and initiating a defrost of the remote evaporator if product is being loaded into the second compartment. In an embodiment, the step of initiating a defrost of at least one of the evaporators comprises the steps of: determining whether the door to a compartment is open, and initiating a defrost of the evaporator associated with that compartment if the door to that compartment is open, and initiating a defrost of the evaporator associated with that compartment if the door to that compartment is open.
determined to be open. In an embodiment, the step of initiating the defrost of an evaporator comprises initiating an electric defrost of the evaporator. In an embodiment, the step of initiating the defrost of an evaporator comprises initiating an electric defrost of the evaporator or a predetermined time period.

Brief Description of the Drawings

[0012] For a further understanding of the invention, reference will be made to the following detailed description of the invention which is to be read in connection with the accompanying drawing, where:

[0013] FIG. 1 is a perspective view, partly in section, of a refrigerated truck trailer having a compartmentalized cargo box and equipped with a transport refrigeration unit having multiple evaporators;

[0014] FIG. 2 is a schematic representation of an exemplary embodiment of the multiple evaporator transport refrigeration unit of the invention;

[0015] FIG. 3 is a block diagram illustrating an exemplary embodiment of the method for operation of the transport refrigeration unit of FIG. 2 during loading of the refrigerated perishable product container of FIG. 1; and

[0016] FIG. 4 is a block diagram illustrating an exemplary embodiment of the step of initiating a defrost mode during loading of the refrigerated perishable product container of FIG. 1.

Detailed Description of the Invention

[0017] Referring now to FIGs. 1 and 2, there is shown a truck trailer 100 having a refrigerated cargo box 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 truck trailer 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 perishable product being
shipped therein. Although the invention will be described herein with reference to the three compartment, refrigerated cargo box, illustrated in Fig. 1, it is to be understood that the invention may also be used in connection with truck trailers having compartmentalized cargo boxes with the cargo compartments arranged otherwise, and also in connection with other refrigerated transport vessels, including for example refrigerated box of a truck, or a refrigerated freight container of compartmentalized design for transporting perishable product by ship, rail and/or road transport.

[0018] The transport refrigeration system 10 includes a refrigeration unit 12 and a power source 14. The refrigeration unit 12 includes compressor 20, a condenser 30 and associated condenser fan(s) 34, a main evaporator 40 and associated evaporator fan(s) 44, remote evaporators 50 and 60 and associated fans 54 and 64, respectively, and evaporator expansion devices 46, 56 and 66 arranged in a conventional refrigeration cycle and connected in a refrigerant circulation circuit including refrigerant lines 2, 4, 6a, 6b, 6c and 8. 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 condenser 30 its associated condenser fan(s) 34 disposed externally of the refrigerated cargo box 110 in a housing 16.

[0019] The main evaporator 40 is disposed on the wall 102 of the forward compartment 112 of the refrigerated cargo box 110. The expansion device 46, which as in the depicted embodiment may be an electronic expansion valve, is disposed in refrigerant line 6a upstream with respect to refrigerant flow of the main evaporator 40 for metering the flow of refrigerant through the evaporator in response to the degree of superheat in the refrigerant at the outlet of the evaporator 40, as in conventional practice. A temperature sensor 41 and a pressure sensor 43 are mounted on the refrigerant line 6a closely downstream of the outlet of the evaporator 40 for monitoring the temperature and pressure of the refrigerant at the evaporator outlet. The electronic expansion valve 46 receives signals indicative of the evaporator outlet temperature and pressure from the sensors 41 and 43, respectively, and determines therefrom the degree of superheat in the refrigerant at the evaporator outlet as in conventional practice.
[0020] The remote evaporator 50 is disposed on the partition wall 104 of the refrigerated cargo box 110 within the central compartment 114. A solenoid operated flow shut-off valve 58 is disposed in refrigerant line 6b upstream with respect to refrigerant flow of the expansion valve 56, which, as in the depicted exemplary embodiment, may be a thermostatic static expansion valve operatively associated with an evaporator outlet temperature sensing element 57, for example a temperature sensing bulb, mounted on refrigerant line 6b downstream with respect to refrigerant flow of the evaporator 50 for sensing the refrigerant temperature at the evaporator outlet which reflects the degree of superheat of the refrigerant at the evaporator outlet. As in conventional practice, the expansion valve 56 meters the flow of refrigerant through the remote evaporator 50. An external equalizer line 59 may also be provided in association with the expansion valve 56.

[0021] The remote evaporator 60 is disposed on the ceiling of the cargo box 110 within the aft compartment 116. A solenoid operated flow shut-off valve 68 is disposed in refrigerant line 6c upstream with respect to refrigerant flow of the expansion valve 66, which, as in the depicted exemplary embodiment, may be a thermostatic static expansion valve operatively associated with an evaporator outlet temperature sensing element 67, for example a temperature sensing bulb, mounted on refrigerant line 6c downstream with respect to refrigerant flow of the evaporator 60 for sensing the refrigerant temperature at the evaporator outlet which reflects the degree of superheat of the refrigerant at the evaporator outlet. As in conventional practice, the expansion valve 66 meters the flow of refrigerant through the remote evaporator 60. An external equalizer line 69 may also be provided in association with the expansion valve 66.

[0022] As in conventional practice, when the refrigeration unit 10 is in operation, low temperature, low pressure refrigerant vapor is compressed by the compressor 20 to a high pressure, high temperature refrigerant vapor and passed from the discharge outlet of the compressor 20 into refrigerant line 2. The refrigerant circulates through the refrigerant circuit via refrigerant line 2 to and through the heat exchanger coil of the condenser 30, wherein the refrigerant vapor condenses to a liquid, and the subcooler 32, thence through refrigerant line 4 through the refrigerant-to-refrigerant heat exchanger 35, thence through refrigerant line 6a through the main evaporator 40, and through
refrigerant lines 6b and 6c and the remote respective evaporator 50 and 60, if the
associated solenoid operated flow shut-off valves 58 and 68 are open. The refrigerant
evaporates as it passes through the evaporators in heat exchange relationship the air
within the respective cargo compartments. The refrigerant vapor leaving the evaporators
thence passes through refrigerant line 8 through the refrigerant-to-refrigerant heat
exchanger 35 and the suction modulation valve 22 to return to the suction inlet of the
compressor 20. In the refrigerant-to-refrigerant heat exchanger 35, the hot, high pressure
liquid refrigerant passing through refrigerant line 4 passes in heat exchange relationship
with the lower temperature, lower pressure vapor refrigerant passing through refrigerant
line 8. In addition, a receiver 16 and a filter/drier 18 may be included in the refrigerant
circuit as in conventional practice. An economizer circuit (not shown) incorporated into
the refrigerant circuit in a conventional manner well known in the art.

[0023] The compressor 20 may comprise a single-stage or multiple-stage
compressor such as, for example, a reciprocating compressor or a scroll compressor,
although the particular type of compressor used is not germane to or limiting of the
invention. In the exemplary embodiment depicted in Fig. 2, the compressor is a
reciprocating compressor, such as for example, an 06D model reciprocating compressor
manufactured by Carrier Corporation or a variant thereof, having a compressing
mechanism, an internal electric compressor motor and an interconnecting drive shaft that
are all sealed within a common housing of the compressor 20. The power source 14 fully
powers the internal electric motor of the compressor. In an embodiment, the power
source 14 generates sufficient electrical power for fully driving the electrical motor of the
compressor 20 and also for providing all other electrical power required by the fans 34,
44, 54, 64 and other parts of the refrigeration system 10. In an electrically powered
embodiment of the transport refrigeration system 10, the power source 14 comprises a
single on-board engine driven synchronous generator configured to selectively produce at
least one AC voltage at one or more frequencies. An electrically powered transport
refrigeration system suitable for use on truck trailer transport vehicles are shown in U.S.
Pat. No. 6,223,546, assigned to the assignee of the present application, the entire
disclosure of which is incorporated herein by reference.
The refrigeration unit also includes an electronic controller 70 that is configured to operate the refrigeration unit 10 to maintain a predetermined thermal environment within the compartments 112, 114 and 116 defined within the cargo box 110 wherein the product is stored during transport. The electronic controller 70 maintains the predetermined environment by selectively powering and controlling the operation of the compressor 20, the condenser fan(s) 34 associated with the condenser 30, the evaporator fans 44, 54 and 64 associated with the evaporators 40, 50 and 60, respectively, and the suction modulation valve 12. When cooling of the environment within the compartments 112, 114 and 116 of the cargo box 110 is required, the electronic controller 70 activates the compressor 20, the condenser fan(s) 34 and the evaporator fan 44, 54 and 64, as appropriate. Additionally, the electronic controller 70 adjusts the position of the suction modulation valve 12 to increase or decrease the flow of refrigerant supplied to the compressor 20 as appropriate to control and stabilize the temperatures within the respective compartments 112, 114 and 116 within the cargo box at the respective set point temperatures, which correspond to the desired product storage temperatures for the particular products stored within the respective compartments 112, 114 and 116 of the cargo box 110. A more detailed discussion of the operation of the transport refrigeration unit 100 under normal steady-state load is provided in the aforementioned U.S. Patent 6,223,546.

In one embodiment, the electronic controller 70 includes a microprocessor and an associated memory. The memory of the controller 70 may be programmed to contain preselected operator or owner desired values for various operating parameters within the system, including, but not limited to, temperature set points for various locations within the refrigerant circuit and/or the compartments 112, 114 and 116 of the cargo box 110, pressure limits, current limits, engine speed limits, and any variety of other desired operating parameters or limits within the system. The programming of the controller is within the ordinary skill in the art. The controller 70 may include a microprocessor board that includes the microprocessor, an associated memory, and an input/output board that contains an analog-to-digital converter which receives temperature inputs and pressure inputs from a plurality of sensors located at various points throughout the refrigerant circuit and the refrigerated cargo box, current inputs,
voltage inputs, and humidity levels. The input/output board may also include drive
circuits or field effect transistors and relays which receive signals or current from the
controller 70 and in turn control various external or peripheral devices associated with the
transport refrigeration system. In an embodiment, the controller 70 may comprise the
MicroLink™ controller available from Carrier Corporation, the assignee of this
application. However, the particular type and design of the controller 70 is within the
discretion of one of ordinary skill in the art to select and is not limiting of the invention.

When the refrigeration unit system 10 is in operation, air within the
forward compartment 112 of the refrigerated cargo box 110 is circulated by the
evaporator fan(s) 44 through the evaporator 40 and back into the interior volume of the
refrigerated forward compartment 112 of the cargo box 110. Additionally, if the
solenoid operated flow shut-off valve 58 is open, air within the central compartment 114
of the refrigerated cargo box 110 is circulated by the evaporator fan(s) 54 through the
evaporator 50 and back into the interior volume of the refrigerated forward compartment
114 of the cargo box 110. If the solenoid operated flow shut-off valve 68 is open, air
within the aft compartment 116 of the refrigerated cargo box 110 is circulated by the
evaporator fan(s) 64 through the evaporator 60 and back into the interior volume of the
refrigerated aft compartment 116 of the cargo box 110. As in conventional practice, the
air passing through the evaporators 40, 50 and 60 is cooled as it passes in heat exchange
relationship with refrigerant circulated through the tubes of the finned heat transfer coils
of the respective evaporators 40, 50 and 60.

Perishable product is loaded into the compartments 112, 114, 116 of the
refrigerated cargo box 110 of the trailer 100 through the doors 113, 115, 117,
respectively. When loading product, it is customary to leave the doors open to facilitate
the loading operation. With the doors open, relatively warmer moisture bearing ambient
air from externally of the cargo box 110 may enter into any of the compartments 112, 114
and 116 whose respective door or doors are open. Relatively colder Refrigerated air may
simultaneously pass out of the interior volume of any compartment whose doors or doors
are open. The net effect being to raise the temperature of and add moisture to the air
resident within the interior volume of those open compartments, particularly in regions
with warm and humid ambient conditions.
Consequently, many operators choose to run the transport refrigeration system 10 during the product loading operation to counter the impact of the infiltration of relatively warmer ambient air and to reduce the time required to pull down the temperature of the interior volume of the compartment(s) and the temperature of the freshly added product within the compartment(s) when the loading operation has been completed. As a result of the increased moisture within the interior volume the compartments of the cargo box 110 being loaded, frost will build-up on the finned tube heat exchanger coil of the main evaporator 40 if compartment 112 is being loaded and the finned tube heat exchanger coils of the remote evaporators 50 and 60 if the compartments 114 and 116, respectively, are being loaded, and will do so more quickly than under normal steady-state operating conditions. As frost builds up on the heat exchanger coils of the respective evaporators, the cooling capacity and the pull down capability of the refrigeration unit 12 decreases and air flow through the affected evaporator decreases.

The controller 70 is configured to determine the degree of superheat in the refrigerant passing through refrigerant line 8 that connects the respective refrigerant lines 6a, 6b and 6c downstream of the respective outlets of the heat exchanger coils of the evaporators 40, 50 and 60 in refrigerant flow communication with the suction inlet of the compressor 20. The controller 70 compares the determined degrees of superheat, commonly referred to as suction superheat (SSV), to a low suction superheat threshold (LSS). If the determined suction superheat (SSV) is less than the low suction superheat threshold (LSS) during the loading operation, the controller 60 will interrupt operation of the refrigeration unit 12 in the refrigeration mode and initiate an electric defrost cycle to clear the heat exchanger coil of the affected evaporator or evaporators of the evaporators 40, 50 and 60 of the frost built-up thereon.

In an embodiment, the controller 70 uses the refrigerant suction temperature and the refrigerant suction pressure to calculate the degree of superheat at the suction inlet. A temperature sensor 72 operatively associated with refrigerant line 8 monitors the temperature of the refrigerant upstream of the suction inlet (CST) of the compressor 20 and a pressure sensor 74 operatively associated with the compressor 20 monitors the pressure of the refrigerant at the suction inlet (CSP) of the compressor 20. In the exemplary embodiment depicted in Fig. 2, the temperature sensor 72 comprises a
thermocouple, thermistor or other conventional thermostatic device mounted on the refrigerant line 8 at a location downstream with respect to refrigerant flow of the suction modulation valve. In the exemplary embodiment depicted in Figure 2, the pressure sensor 74 comprises a conventional pressure transducer mounted in operative association with the suction inlet side of the compression chamber of the compressor 20 to sense the pressure of the refrigerant vapor at the suction inlet.

[0031] The defrost control mode of the controller 70 during the period in which the transport refrigeration system 10 is running while product is being loaded into the cargo box 110 is presented schematically in block diagram of Fig. 3. At block 202, the temperature sensor 72 detects the compressor suction temperature (CST) and transmits a signal indicative of the CST to the input/output module of the controller 70. At block 204, the pressure sensor 74 detects the compressor suction pressure (CSP) and transmits a signal indicative of the CSP to the input/output board of the controller 70. The analog input signals received from the sensors 72 and 74 are converted to digital signals by means of an analog-to-digital converter associated with the input/output module. If the sensors 72 and 74 are of a type that generate and transmit digital signals, rather than analog signals, this conversion is not needed.

[0032] The controller 70 uses the sensed CST and CSP to determine the degrees of superheat in the refrigerant at the suction inlet (CSS) at the current operating conditions of the transport refrigerant unit 12. In an embodiment, at block 206, the controller 70 determines the degree of superheat through reference to a look-up table of suction saturated temperature (SST) versus saturated pressure (equal to CSP) for the refrigerant with which the refrigerant unit 12 is charged and then, at block 208, subtracts that suction saturated temperature (SST) from the sensed compressor suction temperature (CST) to determine the degrees of superheat (CSS) at the suction inlet of the compressor.

[0033] Having determined the actual degrees of superheat of the refrigerant at the suction inlet (CSS) at the compressor suction inlet, at block 210, the controller 70 compares the CSS to a threshold valve representative of the permissible lower limit for the degrees of superheat of the refrigerant at the suction inlet (LSS) to the compressor 20 and indicative of unacceptable frost build-up on one or more of the respective heat exchanger coils of the main evaporator 40 and the remote evaporators 50 and 60.
If the actual degrees of superheat of the refrigerant at the suction inlet (CSS) is equal to or less than the permissible lower limit for the degrees of superheat of the refrigerant at the suction inlet (LSS), the controller 70, at block 212, interrupts the operation of the refrigeration unit 12 in the refrigeration mode and activates the electric defrost elements 80 and deactivates fan or fans 44, 54 and 64, as appropriate, to initiate an electric defrost of the frosted heat exchanger coils of the respective evaporators 40, 50 and 60. After a preprogrammed time delay following initiation of the electric defrost cycle, the extent of which is within the ordinary skill in the art to select for the particular evaporator heat exchanger coils in use, the controller 70 will deactivate the electric defrost elements 80 to terminate the electric defrost cycle and reactivate fan or fans 44, 54 and 64, as appropriate, to return the transport refrigeration unit 12 to operation in the refrigeration mode, at block 214. If, however, the actual degree of superheat of the refrigerant at the suction inlet (CSS) is greater than the permissible lower limit for the degrees of superheat of the refrigerant at the suction inlet (LSS), the controller 70 continues operation of the refrigeration unit 12 in the refrigeration mode.

In an embodiment, the step of initiating the defrost mode may comprise initiating a defrost of the main evaporator if product is being loaded into the first compartment and/or initiating a defrost of the remote evaporator if product is being loaded into the second compartment. Referring now to FIG. 4, the controller 70 will carry out step 212 by first determining which of the doors 113, 115 and 117, associated respectively with compartments 112, 114 and 116 and then initiating a defrost cycle of the main evaporator 40 if, and only if, the door 113 to the forward compartment 112 is open, initiating a defrost of the remote evaporator 50 if, and only if, the door 115 to the central compartment 114 is open, and initiating a defrost of the remote evaporator 60 if, and only if, the door 117 to the aft compartment 116 is open. To facilitate the determination of which of the compartment doors is open during loading of product, a door sensor (not shown) may be installed, as in conventional practice, in operative association with each of the compartment doors to sense whether its associated door is open or closed and transmit a signal to the controller 70 indicating when that the door is open.
While the present invention has been particularly shown and described with reference to the preferred mode as illustrated in the drawing, it will be understood by one skilled in the art that various changes in detail may be effected therein without departing from the spirit and scope of the invention as defined by the claims.
We Claim:

1. A method for operating a transport refrigeration unit during loading of product into a compartmentalized cargo box, the cargo box having at least a first compartment having a door and a second compartment having a door, the refrigeration unit having a refrigerant flow circuit including a refrigerant compressor having a suction inlet, a main evaporator operatively associated with the first compartment and a remote evaporator operative associated with the second compartment, connected in refrigerant flow communication in a refrigeration circuit, said method comprising the steps of:
   - determining a degree of superheat (CSS) in the refrigerant at the suction inlet to the compressor;
   - comparing said degree of suction superheat (CSS) to a lower limit for the degree of superheat (LSS) at the suction inlet to the compressor;
   - continuing operation of said refrigerant unit in a refrigeration mode if said degree of suction superheat (CSS) is greater than said lower limit for the degree of superheat (LSS); and
   - terminating operation of said refrigerant unit in the refrigeration mode if said degree of suction superheat (CSS) is not greater than said lower limit for the degree of superheat (LSS) and initiating a defrost of at least one the first and second evaporators.

2. A method as recited in claim 1 wherein the step of determining a degree of superheat (CSS) in the refrigerant at the suction inlet to the compressor comprises the steps of:
   - sensing a refrigerant temperature (CST) indicative of the refrigerant temperature at the suction inlet to the compressor;
   - sensing a refrigerant pressure (CSP) indicative of the refrigerant pressure at the suction inlet to the compressor;
   - determining a suction saturation temperature (SST) based upon the sensed refrigerant pressure (CSP) indicative of the refrigerant pressure at the suction inlet to the compressor; and
subtracting the suction saturation temperature (SST) from the sensed refrigerant temperature (CST) indicative of the refrigerant temperature at the suction inlet to the compressor.

3. A method as recited in claim 1 wherein the step of initiating a defrost of at least one of said evaporators comprises initiating a defrost of said remote evaporator.

4. A method as recited in claim 1 wherein the step of initiating a defrost of at least one of said evaporators comprises initiating a defrost of said main evaporator if product is being loaded into the first compartment and initiating a defrost of said remote evaporator if product is being loaded into said second compartment.

5. A method as recited in claim 1 wherein the step of initiating a defrost of at least one of said evaporators comprises the steps of;
   determining whether the door to the second compartment is open; and
   initiating a defrost of said remote evaporator if the door to the second compartment is determined to be open.

6. A method as recited in claim 1 wherein the step of initiating a defrost of at least one of said evaporators comprises the steps of;
   determining whether the door to the first compartment is open; and
   initiating a defrost of said main evaporator if the door to the first compartment is determined to be open.

7. A method as recited in claim 1 wherein the step of initiating a defrost of at least one of said evaporators comprises initiating an electric defrost of at least one of said evaporators.

8. A method as recited in claim 1 wherein the step of initiating a defrost of at least one of said evaporators comprises initiating an electric defrost of at least one of said evaporators for a predetermined time period.
9. A method for operating a transport refrigeration unit for cooling the interior of a compartmentalized truck trailer during loading of product into the compartmentalized truck trailer, the truck trailer having at least a first compartment having a door and a second compartment having a door, the refrigeration unit having a refrigerant flow circuit including a refrigerant compressor having a suction inlet, a main evaporator operatively associated with the first compartment and a remote evaporator operative associated with the second compartment, connected in refrigerant flow communication in a refrigeration circuit, said method comprising the steps of:

   determining a degree of superheat (CSS) in the refrigerant at the suction inlet to the compressor;
   comparing said degree of suction superheat (CSS) to a lower limit for the degree of superheat (LSS) at the suction inlet to the compressor;
   continuing operation of said refrigerant unit in a refrigeration mode if said degree of suction superheat (CSS) is greater than said lower limit for the degree of superheat (LSS); and
   terminating operation of said refrigerant unit in the refrigeration mode if said degree of suction superheat (CSS) is not greater than said lower limit for the degree of superheat (LSS) and initiating a defrost of at least one the first and second evaporators.

10. A method as recited in claim 9 wherein the step of determining a degree of superheat (CSS) in the refrigerant at the suction inlet to the compressor comprises the steps of:

   sensing a refrigerant temperature (CST) indicative of the refrigerant temperature at the suction inlet to the compressor;
   sensing a refrigerant pressure (CSP) indicative of the refrigerant pressure at the suction inlet to the compressor;
   determining a suction saturation temperature (SST) based upon the sensed refrigerant pressure (CSP) indicative of the refrigerant pressure at the suction inlet to the compressor; and
subtracting the suction saturation temperature (SST) from the sensed refrigerant
temperature (CST) indicative of the refrigerant temperature at the suction inlet to the
compressor.

11. A method as recited in claim 9 wherein the step of initiating a defrost of at
least one of said evaporators comprises initiating a defrost of said remote evaporator.

12. A method as recited in claim 9 wherein the step of initiating a defrost of at
least one of said evaporators comprises initiating a defrost of said main evaporator if
product is being loaded into the first compartment and initiating a defrost of said remote
evaporator if product is being loaded into said second compartment.

13. A method as recited in claim 9 wherein the step of initiating a defrost of at
least one of said evaporators comprises the steps of;
- determining whether the door to the second compartment is open; and
- initiating a defrost of said remote evaporator if the door to the second
  compartment is determined to be open.

14. A method as recited in claim 9 wherein the step of initiating a defrost of at
least one of said evaporators comprises the steps of;
- determining whether the door to the first compartment is open; and
- initiating a defrost of said main evaporator if the door to the first compartment is
determined to be open.

15. A method as recited in claim 9 wherein the step of initiating a defrost of at
least one of said evaporators comprises initiating an electric defrost of at least one of said
evaporators.

16. A method as recited in claim 9 wherein the step of initiating a defrost of at
least one of said evaporators comprises initiating an electric defrost of at least one of said
evaporators for a predetermined time period.
SENSE CST

SENSE CSP

DETERMINE SST

CSS = CST - SST

COMPARE CSS TO LSS

CSS EQUAL TO OR LESS THAN LSS

212

INITIATE DEFROST MODE

CSS EXCEEDS LSS

214

CONTINUE REFRIGERATION MODE

FIG. 3
FIG. 4
INTERNATIONAL SEARCH REPORT

A CLASSIFICATION OF SUBJECT MATTER
IPC(8) - F25B 29/00 (2007.01)
USPC - 62/161, 208
According to International Patent Classification (IPC) or to both national classification and IPC

B FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8) F25B 29/00 (2007 01)
USPC 62/161, 208

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC 62/161, 208 (see search terms)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
USPTO - West - DB PGPB, USPT, EPAB, JPA
Search terms compressor, evaporator, defrost, temperature, pressure, superheat, electric, transport and door

C DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>US 5,065,587 A (HOWLAND et al) 19 November 1991 (19 11 1991), Figure 1-5, column 2, line 61 to column 3, line 61, column 4, lines 3-55, column 6, lines 36-50, column 8, lines 9-18</td>
<td>1-16</td>
</tr>
<tr>
<td>Y</td>
<td>US 5,168,715 A (NAKAO et al) 08 December 1992 (08 12 1992), Figure 3, 9, 10-a-b, column 4, line 40 to column 5, line 20, column 6, line 22 to column 7, line 10</td>
<td>1-16</td>
</tr>
<tr>
<td>Y</td>
<td>US 6,996,997 B2 (WIFF et al) 14 February 2006 (14 02 2006), Figure 2, 3-a-d, column 3, line 65 to column 4, line 49, column 6, lines 33-54, column 8, lines 15-29, column 11, lines 14-57</td>
<td>1-16</td>
</tr>
</tbody>
</table>

☐ Further documents are listed in the continuation of Box C

D

• Special categories of cited documents
  "A" document defining the general state of the art which is not considered to be of particular relevance
  "E" earlier application or patent but published on or after the international filing date
  "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
  "O" document referring to an oral disclosure, use, exhibition or other means
  "P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance, the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance, the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"Z" document member of the same patent family

Date of the actual completion of the international search
18 August 2007 (18 08 2007)

Date of mailing of the international search report
02 OCT 200?

Name and mailing address of the ISA/US
Mail Stop PCT, Attn ISA/US, Commissioner for Patents
PO Box 1450, Alexandria, Virginia 22313-1450
Facsimile No 571-273-3201

Authorized officer
Lee W Young
PCT Helpdesk 571-272-4300
PCT OSP 571-272 7774

Form PCT/ISA/2 10 (second sheet) (April 2007)