

REFRIGERATION UNIT WITH CORROSION DURABLE HEAT EXCHANGER

Cross-Reference to Related Application

[0001] Reference is made to and this application claims priority from and the benefit of U.S. Provisional Application Serial No. 61/416,815, filed November 24, 2010, entitled "Refrigeration Unit with Corrosion Durable Heat Exchanger", which application is incorporated herein in its entirety by reference.

Field of the Invention

[0002] This invention relates generally to refrigeration units and gas cooler/condenser heat exchangers and, more particularly, to improving condensate drainage and corrosion durability on gas cooler/condenser heat exchangers of transport refrigeration units.

Background of the Invention

[0003] Perishable goods are commonly transported in a controlled environment within an enclosed space such as an insulated cargo box of a truck, trailer, container, or intermodal container. A refrigeration system, also known as a transport refrigeration unit, is used in operative association with the enclosed space within the cargo box for controlling the temperature of the air within the enclosed space within a desired temperature range selected for the particular type of perishable goods stowed within the cargo box. The refrigeration unit is mounted to a wall of the cargo box, typically to the forward end of the cargo box, opposite the doors to the cargo box which are typically at the rear of the cargo box.

[0004] The refrigeration unit includes a refrigerant compressor and condenser disposed externally of the cargo box and an evaporator disposed within the enclosed space of the cargo box, the compressor, condenser and evaporator being connected in a refrigerant circuit in series refrigerant flow relationship. When the refrigeration system is operating, air to be cooled is drawn from within the enclosed space, passes through an evaporator in heat exchange relationship with the refrigerant vapor passing through the heat exchange tubes of the evaporator, and

then supplied back to the enclosed space. The refrigerant vapor having traversed the evaporator is compressed in the compressor to a high temperature, high pressure vapor and then passed through the condenser which functions as a refrigerant heat rejection heat exchanger wherein the high temperature refrigerant vapor passes is heat exchange relationship with cooler air, typically ambient air, or water/glycol solution.

[0005] In conventional prior art transport refrigeration units, the condenser includes a standard round tube plate fin (RTPF) heat exchanger having an array of round tubes penetrating a pack of spaced plate fins. Typically, a plurality of round tubes are inserted through holes in the plates of the fin pack so as to extend longitudinally through the plates of the fin pack and a pair of tube sheets disposed at opposite ends of the fin pack. The ends of the round tubes penetrating the tube sheets are connected by tube bends or return bends to form one or more refrigerant flow circuits through heat exchanger. When installed in the refrigerant unit, the condenser heat exchanger is arranged with the round tubes extended longitudinally in a generally horizontal direction and the fin plates extend in a generally vertical plane. The fin plates are generally flat plates or wavy plates and may include louvers or other fin enhancements to improve air-side heat transfer performance.

[0006] With the condenser heat exchanger extending in a horizontal position as in the prior art, a large amount of space is required. The horizontal arrangement of the heat exchanger coil ensures that any condensate that deposits on the surface of the fins naturally drains off the fins due to the vertical orientation of the plate fins. It is desirable to avoid condensate accumulation on the fin surface as water is an electrolyte, the presence of which on the fin surface can lead to accelerated corrosion. Accordingly, a desire exists for a more compact condenser heat exchanger coil design that promotes adequate water drainage and provides acceptable corrosion durability.

Summary of the Invention

[0007] A transport refrigeration unit is provided which having a refrigerant heat rejection heat exchanger (condenser/gas cooler) that promotes adequate water drainage and corrosion durability. The refrigerant heat rejection heat exchanger

includes a wraparound finned tube coil extending along the periphery of an associated condenser/gas cooler fan. The wraparound finned tube coil has a plurality of heat exchange tube loops and a plurality of plate fins mounted to the plurality of heat exchange tube loops. Each heat exchange tube loop is formed by a plurality of linear tube segments or a plurality of hairpin tubes connected by return bends, with each linear tube segment extending longitudinally at an inclination angle with respect to vertical of at least 20 degrees. In an embodiment, each linear tube segment extends longitudinally at an inclination angle in the range from at least 20 degrees to 90 degrees. Each heat exchange loop may have a generally square configuration, a generally rhombus-like configuration, a generally hexagon-like configuration or other configuration without any significant length of vertically extending tube segments. The fins may be flat plate fins or wavy plate fins, with or without further airside heat transfer enhancements such as louvers, offsets or the like.

Brief Description of the Drawings

[0008] 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:

[0009] FIG. 1 is a perspective view of a refrigerated transport container, equipped with a refrigeration unit, with a portion of the side wall and ceiling removed;

[0010] FIG. 2 is an elevation view of the front of the refrigeration unit mounted to the forward wall of the container of FIG. 1 with the condenser/gas cooler module exposed;

[0011] FIG. 3 is a perspective view of an exemplary embodiment of the refrigerant heat rejection heat exchanger (condenser/gas cooler) disclosed herein;

[0012] FIG. 4 is an elevation view taken generally along line 4-4 of FIG. 3;

[0013] FIG. 5 is a plan view taken generally along line 5-5 of FIG. 4;

[0014] FIG. 6 is a diagrammatic view illustrating an exemplary shape of a single heat exchange tube loop of the wraparound finned tube heat exchanger disclosed herein;

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[0015] FIG. 7 is a diagrammatic view illustrating another exemplary shape of a single heat exchange tube loop of the wraparound finned tube heat exchanger disclosed herein;

[0016] FIG. 8 is an enlarged view of the right hand bend area 8-8 of FIG. 6;

[0017] FIG. 9 is a diagrammatic view illustrating an exemplary embodiment of a single circular heat exchanger loop of the wraparound finned tube heat exchanger disclosed herein; and

[0018] FIG.10 is a diagrammatic view illustrating an exemplary embodiment of a single oval heat exchanger loop of the wraparound finned tube heat exchanger disclosed herein.

Detailed Description of the Invention

[0019] Referring initially to FIG. 1 of the drawing, there is depicted an exemplary embodiment of a refrigerated cargo container, generally referenced 10. The cargo container 10 has an insulated box-like structure formed of a forward or front wall 12, a back or rear wall 14, a pair of opposed sidewalls 13 and 15, a ceiling 16 and a floor 18. The box-like structure defines a cargo space 11 in which the bins, cartons or pallets of cargo 100 being transported are stacked on the floor 18. The rear wall 14 is provided with one or more doors (not shown) through which access to the cargo space may be had for loading the cargo 18 into the container 10. When the doors are closed, a substantially air-tight, sealed cargo space is established within the container 10 which prevents inside air from escaping the cargo space 11.

[0020] A refrigeration unit 20 is mounted to a wall of the container 10. Generally, the refrigeration unit 20 is received in an opening in the forward wall 12 of the container 10 and mounted around its perimeter to the forward wall 12 of the container 10, for example as depicted in FIG. 1, for conditioning the air within the refrigerated chamber 11, i.e. the cargo space of the container 10. Referring now to FIGs. 2 and 3 also, the refrigeration unit 20 includes a compressor 22 with an associated compressor drive motor and a condenser/gas cooler module 24 isolated from the cargo space 11, and an evaporator module operatively associated with the cargo space 11 defined within the container 10. The evaporator module includes a pair of evaporator fans 26 disposed within an upper portion of the refrigeration unit

in air flow communication with the interior volume of the cargo box 11 and an evaporator heat exchanger (not shown) having a plurality of refrigerant conveying tubes through which refrigerant vapor flowing through the refrigeration circuit of the refrigeration unit 20 passes in heat exchange relationship with air to be cooled that is drawn from within cargo space 11 by the evaporator fans 26, passed over the evaporator heat exchanger surface and supplied back to the cargo space.

[0021] The condenser/gas cooler module 24 includes a condenser fan 28 and a refrigerant heat rejection heat exchanger 30 mounted in the forward section of the refrigeration unit 20 external to the cargo space 11. The refrigerant heat rejection heat exchanger 30 may function either as a condenser or as a gas cooler. In refrigeration units wherein the refrigerant heat rejection heat exchanger is a component of a refrigerant vapor compression system operating in a subcritical cycle, the refrigerant heat rejection heat exchanger functions as condenser, that is to condense the high temperature, high pressure refrigerant vapor passing therethrough to a high pressure, lower temperature refrigerant liquid. In refrigeration units wherein the refrigerant heat rejection heat exchanger is a component of a refrigerant vapor compression system operating in a transcritical cycle, the refrigerant heat rejection heat exchanger functions only as a gas cooler, that is to cool, but not condense, the high temperature, high pressure refrigerant vapor passing there through to a high pressure, lower temperature refrigerant vapor.

[0022] The refrigerant heat rejection heat exchanger 30 comprises a finned tube heat exchanger that wraps around the condenser fan 28. For example, as illustrated in FIGs. 3-5, the tubes of the heat exchanger 30, rather than extending longitudinally in a horizontal direction, extend about a periphery of the condenser/gas cooler fan 28 radially outboard of the tips of the blades of the fan 28, which is disposed at the front plane of the refrigeration heat rejection heat exchanger 30. The wraparound finned tube coil 32 has a plurality of heat exchange tube loops 34 and a plurality of plate fins 40 mounted to the plurality of heat exchange tube loops 34. The fins 40 may be flat plate fins or wavy plate fins, as depicted in FIG. 5, with or without further airside heat transfer enhancements, such as louvers, offsets, corrugations or the like.

[0023] The wraparound finned tube coil 32 may have any several tube rows, typically from two to twelve, with at least one tube loop 34, typically two to four, per row. In the embodiment depicted in FIGs. 3-5, the wraparound finned tube heat exchanger 32 has five tube rows with three heat exchange tube loops 34 per row. In operation, the condenser fan 28 draws ambient outdoor air through the refrigerant heat rejection heat exchanger 30 behind the front panel 21 (incoming air flow in direction of arrows) and discharges that air back into the outdoor environment through an opening 23 the front panel 21 of the refrigeration unit 20 about the condenser/gas cooler fan 28. It should be noted that the position of the fan 28 relative to the condenser/gas cooler 30 is not limiting of the invention. Both configurations with fan 28 positioned upstream or downstream of the condenser/gas cooler may be employed, however the latter arrangement is thermodynamically more effective.

[0024] Referring now to FIGs. 6-8 in particular, each heat exchange tube loop 34 is formed by a plurality of linear tube segments or hairpins 36 connected by return bends 38. Each heat exchange tube loop 34 may be formed of a continuous heat exchange tube 40 extending between a pair of tube sheets 42 and 44. As in conventional practice, the ends of the heat exchange tubes 40 penetrating each tube sheet 42 and 44 may be interconnected by U-bends (not shown) to form one or more refrigerant flow circuits, as desired, through the heat exchanger 30 in a manner well-known to those skilled in the art.

[0025] To form each heat exchange tube loop 34, the heat exchange tube 40 is bent as appropriate to delineate a desired shape. For example, the heat exchange tube loop 34 may take the shape of a parallelogram, such as illustrated in the exemplary embodiment depicted in FIG. 6, the heat exchange tube loop 34 is formed by bending the heat exchange tube 40 to delineate a generally square (rhombus with equal included angles) shape extending between tube sheets 42 and 44. The heat exchange tube loop 34 may delineate other shapes also, for example such as in the exemplary embodiment depicted in FIG. 7, where the heat exchange tube loop 34 is formed by bending the heat exchange tube 40 to delineate a generally hexagonal shape extending between the tube sheets 42 and 44. The heat exchange tube loop 34 may also be formed as a non-linear tube loop having, for example, a generally

circular configuration such as illustrated in FIG. 9 or a generally oval confirmation such as illustrated in FIG. 10.

[0026] When the condenser/gas cooler module 24 is installed in the refrigeration unit 20, the refrigerant heat rejection heat exchanger 30 is arranged with the wraparound finned tube heat exchanger coil 32 disposed about the periphery of the condenser/gas cooler fan 28 such that each linear tube segment 36 of each heat exchange loop 34 extends longitudinally at an inclination angle, θ , with respect to vertical, V, of at least 20 degrees. In an embodiment, each linear tube segment extends longitudinally at an inclination angle in the range from at least 20 degrees up to and including 90 degrees, which represents a horizontally extending tube segment. As illustrated in FIG. 8 wherein a single tube of the heat exchange tube loop 34 of the finned tube heat exchanger coil 32 of FIGs. 3-6 with the fins deleted for illustration purposes, the angle of indication, θ , is measured as the interior included angle between the longitudinal axis of the linear tube segment 36 and a vertical axis, V.

[0027] By ensuring that all linear segments 36 of the heat exchange tube loops 34 extend longitudinally at an indication from the vertical position of at least 20 degrees, adequate drainage of water collecting on the surface of the plate fins 40, as a result of rain or as condensate from moisture in the air placing through the refrigerant heat rejection heat exchanger under high humidity conditions, is assured since the plate fins 40 extend orthogonally to the longitudinal axis of the linear segments 36 of the heat exchange tube loops 34. Positive drainage of water is ensured even in the case of wavy plate fins wherein water tends to collect in the valleys of the wavy plate fins.

[0028] If the linear segments 36 of the heat exchange tube loop 34 were to extend generally vertically, contrary to the teachings of this disclosure, the plate fins 40 would extend generally horizontally which would in no way promote drainage of water from the within surface and, in the case of wavy plate fins, allow accumulation of water in the valleys of the wavy plate fins. Over time, since water accumulating on the surface of the plate fins acts as an electrolyte initiating and accelerating the corrosion process, the corrosion durability of the plate fins would be significantly shortened.

[0029] The terminology used herein is for the purpose of description, not limitation. Specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as basis for teaching one skilled in the art to employ the present invention. Those skilled in the art will also recognize the equivalents that may be substituted for elements described with reference to the exemplary embodiments disclosed herein without departing from the scope of the present invention. Also, the invention can be equally applied to refrigeration, air conditioning and heat pump systems.

[0030] Furthermore, heat rejection heat exchanger construction can comprise more than one heat rejection heat exchanger. For instance, condenser/gas cooler and intercooler as well as condenser/gas cooler and radiator can be integrated in a single module and formed (bent) at the same time. The former configurations may be utilized in high efficiency systems and the latter designs applied in the HVAC&R systems driven by the engine.

[0031] While the present invention has been particularly shown and described with reference to the exemplary embodiments as illustrated in the drawing, it will be recognized by those skilled in the art that various modifications may be made without departing from the spirit and scope of the invention. For example, although the wraparound finned tube heat exchanger 32 was described herein as having round heat exchange tubes, it is to be understood that the heat exchange tubes could instead be non-round tubes, such as multichannel flattened tubes of generally rectangular or oval cross-section. Therefore, it is intended that the present disclosure not be limited to the particular embodiment(s) disclosed as, but that the disclosure will include all embodiments falling within the scope of the appended claims.

We claim:

1. A transport refrigeration unit (20) for conditioning air within a refrigerated cargo box (10) for housing perishable goods during transport, comprising:

a refrigerant heat rejection heat exchanger (30) and a fan (28) operatively associated with the heat exchanger (30), the refrigerant heat rejection heat exchanger (30) including a wraparound finned tube coil (32) extending along a periphery radially outboard of the fan (28), the wraparound finned tube coil (32) having a plurality of heat exchange tube loops (34) and a plurality of plate fins (40) mounted to the plurality of heat exchange tube loops (34), each heat exchange tube loop (34) formed by a plurality of linear tube segments (36) connected by tube bends (38), the refrigerant heat rejection heat exchanger being disposed on a vertical wall of the transport refrigeration unit and each linear tube segment (36) extending longitudinally at an inclination angle (θ) with respect to vertical of at least 20 degrees.

2. The transport refrigeration unit (20) as recited in claim 1 wherein each linear tube segment (36) extends longitudinally at an inclination angle (θ) in the range from at least 20 degrees to 90 degrees.

3. The transport refrigeration unit (20) as recited in claim 1 wherein the plurality of plate fins (40) comprises a plurality of plates having a wavy configuration.

4. The transport refrigeration unit (20) as recited in claim 3 wherein the plurality of plate fins (40) include heat transfer enhancements.

5. The transport refrigeration unit (20) as recited in claim 1 wherein each heat exchange tube loop (34) has a generally square-like configuration.

6. The transport refrigeration unit (20) as recited in claim 1 wherein each heat exchange tube loop (34) has a generally rhombus-like configuration.

7. The transport refrigeration unit (20) as recited in claim 1 wherein each heat exchange tube loop has a generally hexagon-like configuration.

8. The transport refrigeration unit (20) as recited in claim 1 wherein the refrigerant unit (20) operates in a subcritical cycle and the refrigerant heat rejection heat exchanger (30) operates as a condenser.

9. The transport refrigeration unit (20) as recited in claim 1 wherein the refrigerant unit (20) operates in a transcritical cycle and the refrigerant heat rejection heat exchanger (30) operates as a gas cooler.

10. The transport refrigeration unit (20) as recited in claim 1 wherein the refrigerant heat rejection heat exchanger (30) comprises more than one refrigerant heat rejection heat exchangers (30).

11. The transport refrigeration unit (20) as recited in claim 1 wherein the more than one heat rejection heat exchangers (30) include condenser/gas cooler and intercooler.

12. The transport refrigeration unit (20) as recited in claim 1 wherein the more than one heat rejection heat exchangers (30) include condenser/gas cooler and radiator.