Scrubber System With Moving Adsorbent Bed

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. 61/508,872, filed July 18, 2011, and entitled SCRUBBER SYSTEM WITH MOVING ADSORBENT BED.

Background of the Invention

[0002] This invention relates generally to controlling the composition of the atmosphere within a closed environment and, more particularly to the removal of carbon dioxide, and optionally other byproduct of gases from the respiration of fresh produce, from an atmosphere within a closed environment, such as the cargo box of a refrigerated transport container.

[0003] Perishable goods are commonly transported in a controlled environment within an enclosed space such as a cargo box of a truck, trailer, sea container, or intermodal container. A refrigeration system, also known as a transport refrigeration system, is used in operative association with the enclosed space within the cargo box for controlling the temperature of the air within the enclosed space. The refrigeration system is operative to maintain the air temperature within the enclosed space within a desired temperature range selected for the particular type of perishable goods stowed within the cargo box. The refrigeration system includes a refrigeration unit including a refrigerant compressor and condenser disposed externally of the cargo box and an evaporator disposed in operative association with the enclosed space of the cargo box. The compressor, condenser and evaporator are connected in a refrigerant circuit in series refrigerant flow relationship in a refrigeration cycle. When the refrigeration system is operating, air is drawn from within the enclosed space by a fan or fans associated with the evaporator, passed through an evaporator disposed within the enclosed space in heat exchange relationship with the refrigerant circulating through the refrigerant circuit to be cooled, and cooled air is then supplied back to the enclosed space.

[0004] Certain perishable produce, such as fresh fruits, vegetables and flowers, produce carbon dioxide as a product of the respiration process. In a closed environment, due to post harvest respiration, the carbon dioxide concentration rises and the oxygen concentration drops in the atmosphere within the closed environment. If the oxygen concentration gets too low or the carbon dioxide concentration gets too high, the produce can spoil. Additionally, certain fruits and vegetables and flowers release ethylene and/or ethylene compounds as a byproduct of the ripening process. The presence of ethylene based gases within the enclosed space of the cargo box is known to accelerate the ripening process.

[0005] To alleviate these conditions, it is known to introduce fresh air into the closed environment within the cargo box, while simultaneously venting overboard air from the closed environment within the cargo box. Various air exchange systems are available for use in connection with the transport of perishable cargo. For example, U.S. Pat. No. 6,763,677 discloses a manually operated fresh air vent associated with a refrigerated transport container for providing fresh air to the circulating air and exhausting a portion of the circulating air exteriorly of the cargo box of the container.

[0006] It is also known in the art to delay ripening of a perishable produce in transit within a container or other enclosed cargo storage space by providing a controlled atmosphere within the enclosed cargo storage space. Typically, a high nitrogen, low oxygen atmosphere is provided by either replacing the atmospheric air within the enclosed cargo storage space with nitrogen gas prior to shipment or displacing the atmospheric air within nitrogen generated by an onboard system that extracts nitrogen from the ambient air. The former approach may be suitable for well sealed containers over a short haul, but inadequate for long haul transport of perishable produce. The latter approach is generally considered more suitable for longer haul transport of perishable produce, but requires higher capital costs, as well as higher operating costs.

[0007] It is also known to remove carbon dioxide from the atmosphere within an enclosed space by passing the gas from within the enclosed space through a non-regenerative bed of carbon dioxide adsorbent to scrub carbon dioxide from the gas

passing through the adsorbent bed. However non-regenerative systems lose scrubbing efficiency as the adsorbent bed becomes saturated and the carbon dioxide adsorbent material must be replaced. Therefore, such non-regenerative systems have limited application, particularly in the long haul transport of perishable produce.

Summary of the Invention

[0008] A regenerative carbon dioxide removal system is provided onboard the container through which air from within the cargo box may be circulated for removing at least a portion of the carbon dioxide present in the air. The regenerative carbon dioxide removal system includes a scrubber module containing a carbon dioxide adsorbent material, and an actuator for moving the scrubber module to pass the carbon dioxide adsorbent material alternately between a first flow of air to be cleaned drawn by the evaporator fan from within the cargo box, and a second flow of air drawn from an environment outside the cargo box for regenerating the carbon dioxide adsorbent material by removing collected carbon dioxide from the carbon dioxide adsorbent material.

[0009] A method is provided for controlling the concentration of carbon dioxide in a gaseous atmosphere within a closed environment to maintain the concentration of carbon dioxide in the gaseous atmosphere within the closed environment at a desired level, the method including the step of passing a carbon dioxide adsorbent material alternately between a first flow of air to be cleaned drawn by the evaporator fan from within the cargo box, and a second flow of air drawn from an environment outside the cargo box for regenerating the carbon dioxide adsorbent material by removing collected carbon dioxide from the carbon dioxide adsorbent material.

Brief Description of the Drawings

[0010] For a further understanding of the disclosure, reference will be made to the following detailed description which is to be read in connection with the accompanying drawing, wherein:

We Claim:

1. A regenerative scrubber system for removing carbon dioxide from the atmosphere within a cargo box of a refrigerated transport container equipped with a refrigeration unit having an evaporator heat exchanger and an associated fan disposed in air flow communication with the cargo box, the regenerative scrubber system comprising:

a scrubber module containing a carbon dioxide adsorbent material; and

an actuator for moving the scrubber module to pass the carbon dioxide adsorbent material alternately between a first flow of air drawn by the evaporator fan from within the cargo box and a second flow of air from an environment outside the cargo box.

2. The regenerative scrubber system as set forth in claim 1 wherein the actuator comprises a rotary actuator for rotating the scrubber module about an axis of rotation through the first flow of air and the second flow of air in sequence.

3. The regenerative scrubber system as set forth in claim 2 wherein the scrubber module is mounted in a partition panel separating a condenser module of the refrigeration unit from an evaporator module of the refrigeration unit; and the actuator rotates the scrubber module through the evaporator module and the condenser module.

4. The regenerative scrubber system as set forth in claim 2 wherein the scrubber module is disposed in an evaporator module of the refrigeration unit on a high pressure side of an evaporator fan.

5. The regenerative scrubber system as set forth in claim 1 wherein the scrubber module comprises a rotating wheel mounted to a shaft driven by the rotary actuator and having a body with a screened floor for housing the carbon dioxide adsorbent material.

6. The regenerative scrubber system as set forth in claim 5 wherein the carbon dioxide adsorbent material comprises a porous mass of carbon dioxide adsorbent material in the form of a packed bed of particles or extruded pellets.

7. The regenerative scrubber system as set forth in claim 5 wherein the carbon dioxide adsorbent material comprises a spiral winding or concentric rings of a fabric made from or coated with the carbon dioxide adsorbent material.

8. The regenerative scrubber system as set forth in claim 5 wherein the carbon dioxide adsorbent material further comprises an ethylene adsorbent material.

9. The regenerative scrubber system as set forth in claim 1 further comprising a heater for heating the second flow of air.

10. The regenerative scrubber system as set forth in claim 9 wherein the heater comprises a heat exchanger wherein the second flow of air passes in heat exchange relationship with a flow of engine exhaust gases.

11. The regenerative scrubber system as set forth in claim 2 wherein the actuator comprises a rotary actuator for rotating the scrubber module about an axis of rotation through the first flow of air and the second flow of air and a third flow of air in sequence, the third flow of air comprising a flow of cooling air.

12. The regenerative scrubber system as set forth in claim 1 further comprising coiling coil for cooling the first flow of air prior to the first flow of air passing through the carbon dioxide adsorbent material.

13. The regenerative scrubber system as set forth in claim 1 wherein the actuator comprises a push-pull actuator for translating the scrubber module back and forth between the first flow of air and the second flow of air.

14. The regenerative scrubber system as set forth in claim 13 wherein the scrubber module comprises a sliding drawer translatable within a stationary housing and having a first compartment and a second compartment, each compartment housing carbon dioxide adsorbent

material, the push-pull actuator operative for translating the sliding drawer to either a forward position or a rearward position within the stationary housing.

15. A method for controlling the concentration of carbon dioxide in the atmosphere within a cargo box of a refrigerated transport container to maintain the concentration of carbon dioxide in the atmosphere within the cargo box at a desired level, the method comprising the step of passing a carbon dioxide adsorbent material alternately between a first flow of air to be cleaned from within the cargo box drawn by an evaporator fan associated with the refrigerated transport container, and a second flow of air drawn from an environment outside the cargo box for regenerating the carbon dioxide adsorbent material by removing collected carbon dioxide from the carbon dioxide adsorbent material.

16. The method as set forth in claim 15 wherein the second flow of air comprises ambient air drawn from external the refrigerated transport container.

17. The method as set forth in claim 15 wherein the second flow of air comprises drawn from external the refrigerated transport container and heated before passing through the carbon dioxide adsorbent material.

18. The method as set forth in claim 15 wherein the second flow of air comprises condenser/gas cooler exhaust air having passed through a condenser/gas cooler of a transport refrigeration unit associated with the refrigerated transport container.

19. The method as set forth in claim 15 further comprising passing a flow of cooling air through the carbon dioxide adsorbent material for cooling the carbon dioxide adsorbent material passing from the second flow of air to the first flow of air.

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Background of the Invention

[0002] This invention relates generally to controlling the composition of the atmosphere within a closed environment and, more particularly to the removal of carbon dioxide, and optionally other byproduct of gases from the respiration of fresh produce, from an atmosphere within a closed environment, such as the cargo box of a refrigerated transport container.

[0003] Perishable goods are commonly transported in a controlled environment within an enclosed space such as a cargo box of a truck, trailer, sea container, or inter-modal container. A refrigeration system, also known as a transport refrigeration sys-tem, is used in operative association with the enclosed space within the cargo box for controlling the temperature of the air within the enclosed space. The refrigeration system is operative to maintain the air temperature within the enclosed space within a desired temperature range selected for the particular type of perishable goods stowed within the cargo box. The refrigeration system includes a refrigeration unit including a refrigerant compressor and condenser disposed externally of the cargo box and an evap-orator disposed in operative association with the enclosed space of the cargo box. The compressor, condenser and evaporator are connected in a refrigerant circuit in series refrigerant flow relationship in a refrigeration cycle. When the refrigeration system is operating, air is drawn from within the enclosed space by a fan or fans associated with the evaporator, passed through an evaporator disposed within the enclosed space in heat exchange relationship with the refrigerant circulating through the refrigerant circuit to be cooled, and cooled air is then supplied back to the enclosed space.

[0004] Certain perishable produce, such as fresh fruits, vegetables and flowers, produce carbon dioxide as a product of the respiration process. In a closed environment, due to post harvest respiration, the carbon dioxide concentration rises and the oxygen concentration drops in the atmosphere within the closed environment. If the oxygen concentration gets too low or the carbon dioxide concentration gets too high, the produce can spoil. Additionally, certain fruits

and vegetables and flowers release ethylene and/or ethylene compounds as a byproduct of the ripening process. The presence of ethylene based gases within the enclosed space of the cargo box is known to accelerate the ripening process.

[0005] To alleviate these conditions, it is known to introduce fresh air into the closed environment within the cargo box, while simultaneously venting overboard air from the closed environment within the cargo box. Various air exchange systems are available for use in connection with the transport of perishable cargo. For example, U.S. Pat. No. 6,763,677 discloses a manually operated fresh air vent associated with a refrigerated transport container for providing fresh air to the circulating air and exhausting a portion of the circulating air exteriorly of the cargo box of the container. U.S. Pat. No. 4,701,189 on the other hand discloses a recirculating sorption bed system in which one section is in sorption duty whilst another section is being regenerated thermally; and U.S. Pat. No. 5,451,248 discloses a adsorption apparatus for the selective adsorption in whole or in part (and in a predetermined order) of any H_20 vapour, CO_2, O_2 or C_2H_4 in the vicinity of the adsorption apparatus.

[0006] It is also known in the art to delay ripening of a perishable produce in transit within a container or other enclosed cargo storage space by providing a con-trolled atmosphere within the enclosed cargo storage space. Typically, a high nitrogen, low oxygen atmosphere is provided by either replacing the atmospheric air within the enclosed cargo storage space with nitrogen gas prior to shipment or displacing the atmospheric air within nitrogen generated by an onboard system that extracts nitrogen from the ambient air. The former approach may be suitable for well sealed containers over a short haul, but inadequate for long haul transport of perishable produce. The latter approach is generally considered more suitable for longer haul transport of

perishable produce, but requires higher capital costs, as well as higher operating costs.

[0007] It is also known to remove carbon dioxide from the atmosphere within an enclosed space by passing the gas from within the enclosed space through a non-regenerative bed of carbon dioxide adsorbent to scrub carbon dioxide from the gas passing through the adsorbent bed. However non-regenerative systems lose scrubbing efficiency as the adsorbent bed becomes saturated and the carbon dioxide adsorbent material must be replaced. Therefore, such non-regenerative systems have limited application, particularly in the long haul transport of perishable produce.

Summary of the Invention

[0008] A regenerative carbon dioxide removal system is provided onboard the container through which air from within the cargo box may be circulated for removing at least a portion of the carbon dioxide present in the air. The regenerative carbon di-oxide removal system includes a scrubber module containing a carbon dioxide adsor-bent material, and an actuator for moving the scrubber module to pass the carbon di-oxide adsorbent material alternately between a first flow of air to be cleaned drawn by the evaporator fan from within the cargo box, and a second flow of air drawn from an environment outside the cargo box for regenerating the carbon dioxide adsorbent mater-ial by removing collected carbon dioxide from the carbon dioxide adsorbent material.

[0009] A method is provided for controlling the concentration of carbon dioxide in a gaseous atmosphere within a closed environment to maintain the concentration of carbon dioxide in the gaseous atmosphere within the closed environment at a desired level, the method including the step of passing a carbon dioxide adsorbent material alternately between a first flow of air to be cleaned drawn by the evaporator fan from within the cargo box, and a second flow of air drawn from an environment outside the cargo box for regenerating the carbon dioxide adsorbent material by removing collected carbon dioxide from the carbon dioxide adsorbent material.

Brief Description of the Drawings

[0010] For a further understanding of the disclosure, reference will be made to the following detailed description which is to be read in connection with the accompanying drawing, wherein:

Amended Claims

1. Refrigerated transport container equipped with a refrigeration unit having

a cargo box (12),

a compressor (22) and a condenser/gas cooler module isolated from the cargo box (12) by a partition wall (18),

an evaporator module comprising an evaporator heat exchanger (28) and an associated evaporator fan (30) disposed in air flow communication with the cargo box (12), and

a regenerative scrubber system for removing carbon dioxide from the atmosphere within the cargo box (12), the regenerative scrubber system comprising:

a scrubber module (40) containing a carbon dioxide adsorbent material (42); and

an actuator (50) for moving the scrubber module (40) to pass the carbon dioxide adsorbent (42) material alternately between a first flow of air to be cleaned drawn by the evaporator fan (30) from within the cargo box (12) and from which carbon dioxide is to be removed, and a second flow of air from an environment outside the cargo box (12) for regenerating the carbon dioxide adsorbent material (42) by removing collected carbon dioxide from the carbon dioxide adsorbent material (42).

2. Refrigerated transport container as set forth in claim 1, wherein the condenser/gas cooler module includes a condenser/gas cooler heat exchanger (24) functioning as a refrigerant heat rejection heat exchanger, mounted in the forward section of the transport refrigeration unit (20) external to the cargo box (12) and positioned in association with one or more condenser/gas cooler fans (26) for drawing ambient air from outside the cargo box (12) and for passing that air through the condenser/gas cooler heat exchanger (24) and exhausting that air back into the environment outside the cargo box (12).

3. Refrigerated transport container as set forth in claim 2, wherein the evaporator module includes an evaporator heat exchanger (28) constituting a refrigerant heat absorption heat

exchanger, and one or more evaporator fans (30) configured to draw air (32) from the cargo box (12) through a return air opening (15) in the partition wall (18) to pass through the evaporator heat exchanger (28) and to supply the conditioned air (34) back into the cargo box (12) through a supply air opening (17) in the partition wall (18).

4. Refrigerated transport container as set forth in claim 3, wherein the compressor (22), the condenser/gas cooler heat exchanger (24) and the evaporator heat exchanger (28) are disposed in refrigeration cycle arrangement whereby the circulating air is cooled when passing through the evaporator heat exchanger (28) in heat exchange relationship with the refrigerant.

5. Refrigerated transport container as set forth in claim 4, wherein the condenser/gas cooler fan (26) is configured to pass air from outside the cargo box (12) through that portion of the carbon dioxide adsorbent material in a regeneration mode, and thence exhaust the carbon dioxide laden regeneration air overboard back into the atmosphere outside the cargo box (12), or wherein a dedicated fan (36) separate from the condenser/gas cooler fan (26) is provided, said fan (36) being configured to pass air from outside the cargo box (12) through that portion of the carbon dioxide adsorbent material in a regeneration mode, and thence exhaust the carbon dioxide laden regeneration air overboard back into the atmosphere outside the cargo box (12).

6. Refrigerated transport container as set forth in claim 1, wherein the actuator (50) comprises a rotary actuator for rotating the scrubber module (40) about an axis of rotation through the first flow of air and the second flow of air in sequence.

7. Refrigerated transport container as set forth in claim 6, wherein the scrubber module (40) is mounted in a partition panel (18) separating a condenser module of the refrigeration unit (20) from an evaporator module of the refrigeration unit (20); and the actuator (50) rotates the scrubber module (40) through the evaporator module and the condenser module; or

wherein the scrubber module (40) is disposed in an evaporator module of the refrigeration unit (20) on a high pressure side of an evaporator fan (30).

8. Refrigerated transport container as set forth in claim 1, wherein the scrubber module (40) comprises a rotating wheel (46) mounted to a shaft driven by the rotary actuator and having a body with a screened floor for housing the carbon dioxide adsorbent material (42).

9. Refrigerated transport container as set forth in claim 8, wherein the carbon dioxide adsorbent material (42) comprises a porous mass of carbon dioxide adsorbent material (42) in the form of a packed bed of particles or extruded pellets; or

wherein the carbon dioxide adsorbent material (42) comprises a spiral winding or concentric rings of a fabric made from or coated with the carbon dioxide adsorbent material (42); or

wherein the carbon dioxide adsorbent material (42) further comprises an ethylene adsorbent material.

10. Refrigerated transport container as set forth in claim 1, further comprising a heater (37) for heating the second flow of air; and/or

wherein the heater (37) comprises a heat exchanger wherein the second flow of air passes in heat exchange relationship with a flow of engine exhaust gases.

11. Refrigerated transport container as set forth in claim 6, wherein the actuator (50) comprises a rotary actuator for rotating the scrubber module (40) about an axis of rotation through the first flow of air and the second flow of air and a third flow of air in sequence, the third flow of air comprising a flow of cooling air.

12. Refrigerated transport container as set forth in claim 1, further comprising coiling coil (80) for cooling the first flow of air prior to the first flow of air passing through the carbon dioxide adsorbent material.

13. A method for controlling the concentration of carbon dioxide in the atmosphere within a cargo box (12) of a refrigerated transport container to maintain the concentration of carbon dioxide in the atmosphere within the cargo box (12) at a desired level, wherein the refrigerated transport container comprises a compressor (22) and a condenser/gas cooler module

isolated from the cargo box (12) by a partition wall (18), an evaporator module comprising an evaporator heat exchanger (28) and an associated evaporator fan (30) disposed in air flow communication with the cargo box (12), and a regenerative scrubber system for removing carbon dioxide from the atmosphere within the cargo box (12), the regenerative scrubber system comprising a scrubber module (40) containing a carbon dioxide adsorbent material (42) and an actuator (50), the method comprising the step of moving the scrubber module (40), by the actuator (50), to pass the carbon dioxide adsorbent material (42) alternately between a first flow of air to be cleaned from within the cargo box (12) drawn by an evaporator fan (30) associated with the refrigerated transport container, and a second flow of air drawn from an environment outside the cargo box (12) for regenerating the carbon dioxide adsorbent material (42) by removing collected carbon dioxide from the carbon dioxide adsorbent material (42).

14. The method as set forth in claim 13 wherein the second flow of air comprises ambient air drawn from external the refrigerated transport container; or

wherein the second flow of air comprises drawn from external the refrigerated transport container and heated before passing through the carbon dioxide adsorbent material (42); or

wherein the second flow of air comprises condenser/gas cooler exhaust air having passed through a condenser/gas cooler of a transport refrigeration unit associated with the refrigerated transport container.

15. The method as set forth in claim 13 further comprising passing a flow of cooling air through the carbon dioxide adsorbent material (42) for cooling the carbon dioxide adsorbent material (42) passing from the second flow of air to the first flow of air.