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## (54) Title: CONTROLLED ATMOSPHERE SYSTEM FOR A TRANSPORT UNIT

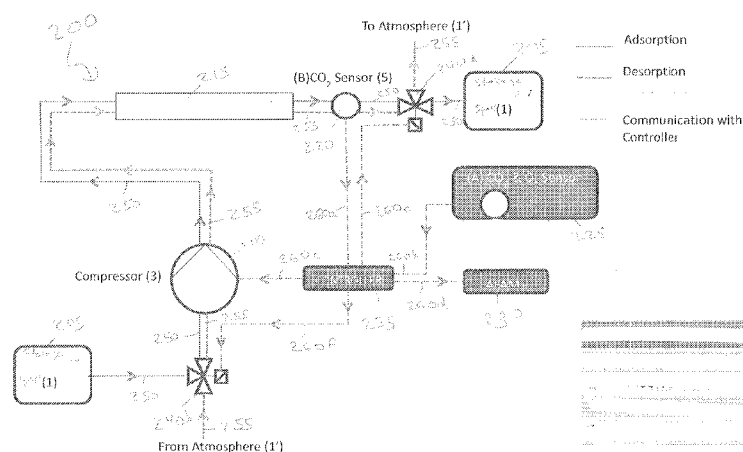


Fig. 2

(57) Abstract: A method and system for continuous control of CO<sub>2</sub> and O<sub>2</sub> levels within a storage space of a transport unit is provided. In particular, the method and system described herein can control regeneration of an activated carbon filter of a CO<sub>2</sub> filter when the activated carbon filter is at or near a saturation point and may no longer be able to absorb CO<sub>2</sub>. The method and system can monitor and control the CO<sub>2</sub> filter based on real time monitoring of the CO<sub>2</sub> filter, based on fixed interval monitoring of the CO<sub>2</sub> filter, and by a predetermined respiration profile of cargo being stored in the storage space of the transport unit.

## CONTROLLED ATMOSPHERE SYSTEM FOR A TRANSPORT UNIT

### Field

The disclosure herein relates to a method and system directed to atmosphere control in a storage space of, for example, a transport unit.

### Background

In a storage space of, for example, a transport unit, atmosphere in the storage space can be controlled to help prolong shelf life of perishable goods, such as for example fruits and vegetables. In some cases, for example, nitrogen separated from the ambient air can be supplied to the storage space, so that, for example, an oxygen concentration and/or carbon dioxide concentration in the storage space can be controlled. Controlling the atmosphere in the storage space can, for example, reduce ripening effect of the perishable goods, which can help prolong the shelf life of the perishable goods.

### Summary

A method and system for controlling an atmosphere in a storage space (e.g., a storage space of a transport unit) is disclosed. The embodiments described herein provide a method and system for controlling an oxygen concentration and/or carbon dioxide concentration in the storage space.

The embodiments described herein can provide continuous control of CO<sub>2</sub> and O<sub>2</sub> levels within a storage space of a transport unit by, for example, regenerating an activated carbon filter of a CO<sub>2</sub> filter when the activated carbon filter is at or near a saturation point and may no longer be able to absorb CO<sub>2</sub>.

In particular, a controlled atmosphere system is provided that allows a storage space with stored cargo (e.g., bananas) to reach a desired CO<sub>2</sub> level and a desired O<sub>2</sub> level by natural respiration of the stored cargo. When a CO<sub>2</sub> level in the storage space reaches a high level carbon dioxide threshold, a controller of the CAS can start an adsorption cycle such that CO<sub>2</sub>

rich air within the storage space is directed to pass through a CO<sub>2</sub> filter to remove (e.g., scrub) CO<sub>2</sub>. The controller can run the adsorption cycle until a saturation point of the CO<sub>2</sub> filter is or about to be reached such that the CO<sub>2</sub> filter would no longer be able to absorb CO<sub>2</sub>. The controller can run a desorption cycle to re-activate the CO<sub>2</sub> filter (e.g., re-activate an activated carbon filter of the CO<sub>2</sub> filter). The controller can monitor and control the CO<sub>2</sub> filter based on real time monitoring of the CO<sub>2</sub> filter, based on fixed interval monitoring of the CO<sub>2</sub> filter, and by a predetermined respiration profile of cargo being stored in the storage space of the transport unit. The controller can also operate a fresh air control mechanism to open when a O<sub>2</sub> level within the storage space falls below a low level oxygen threshold.

Other features and aspects of the systems, methods, and control concepts will become apparent by consideration of the following detailed description and accompanying drawings.

### **Brief Description of the Drawings**

Reference is now made to the drawings in which like reference numbers represent corresponding parts throughout.

Fig. 1 illustrates a climate controlled transport unit, with which the embodiments disclosed herein can be practiced.

Fig. 2 illustrates a schematic diagram of controlled atmosphere system that can provide real time monitoring of a CO<sub>2</sub> filter, according to one embodiment.

Fig. 3 illustrates a flowchart of a method of controlling the controlled atmosphere system shown in Fig. 2, according to one embodiment.

Fig. 4 illustrates a schematic diagram of controlled atmosphere system that can provide real time monitoring of a CO<sub>2</sub> filter, according to another embodiment.

Fig. 5 illustrates a flowchart of a method of controlling the controlled atmosphere system shown in Fig. 4, according to one embodiment.

Fig. 6 illustrates a schematic diagram of controlled atmosphere system that can provide fixed interval monitoring of a CO<sub>2</sub> filter, according to one embodiment.

Fig. 7 illustrates a flowchart of a method of controlling the controlled atmosphere system

shown in Fig. 6, according to one embodiment.

Fig. 8 illustrates a flowchart of a method of controlling a controlled atmosphere system based on a respiration profile of cargo to be stored in a storage space of a transport unit, according to one embodiment.

5 Like reference numbers represent like parts throughout.

### Detailed Description

Perishable goods, such as fruits and vegetables, can consume oxygen and produce carbon dioxide (e.g. due to a ripening effect of the perishable goods) when being stored or in transport.

10 The ripening effect can reduce shelf life of the perishable goods. To help prolong the shelf life of the perishable goods, atmosphere in a storage space of, for example, a transport unit can be controlled. During transport, the ripening effect of the perishable goods can continuously cause the concentrations of the oxygen and/or carbon dioxide in the storage space to change, which may cause undesirable effects on the shelf life of the goods. It may be desired to control the  
15 atmosphere in the storage space during transport and/or storage of the perishable goods.

The embodiments described herein can provide continuous control of CO<sub>2</sub> and O<sub>2</sub> levels within a storage space of a transport unit by, for example, regenerating an activated carbon filter of a CO<sub>2</sub> filter when the activated carbon filter is at or near a saturation point and may no longer be able to absorb CO<sub>2</sub>.

20 In particular, a controlled atmosphere system is provided that allows a storage space with stored cargo (e.g., bananas) to reach a desired CO<sub>2</sub> level and a desired O<sub>2</sub> level by natural respiration of the stored cargo. When a CO<sub>2</sub> level in the storage space reaches a high level carbon dioxide threshold, a controller of the CAS can start an adsorption cycle such that CO<sub>2</sub> rich air within the storage space is directed to pass through a CO<sub>2</sub> filter to remove (e.g., scrub)  
25 CO<sub>2</sub>. The controller can run the adsorption cycle until a saturation point of the CO<sub>2</sub> filter is or about to be reached such that the CO<sub>2</sub> filter would no longer be able to absorb CO<sub>2</sub>. The controller can run a desorption cycle to re-activate the CO<sub>2</sub> filter (e.g., re-activate an activated carbon filter of the CO<sub>2</sub> filter). The controller can monitor and control the CO<sub>2</sub> filter based on real time monitoring of the CO<sub>2</sub> filter, based on fixed interval monitoring of the CO<sub>2</sub> filter, and

by a predetermined respiration profile of cargo being stored in the storage space of the transport unit. The controller can also operate a fresh air control mechanism to open when a O<sub>2</sub> level within the storage space falls below a low level oxygen threshold.

5 A climate controlled transport unit (CCTU) includes, for example, a transport unit having a controlled atmosphere system (CAS). A CCTU can be used to transport perishable items such as, but not limited to, produce, frozen foods, and meat products. A transport unit, as described herein, includes e.g., a marine container, a container on a flat car, an intermodal container, truck, a boxcar, an air cargo cabin, or other similar transport unit.

10 The CAS can include, without limitation, an air compressor, a CO<sub>2</sub> filter, one or more carbon dioxide sensors, one or more oxygen sensors, a fresh air exchange mechanism to control the carbon dioxide concentration and oxygen concentration between the air within the storage space and the ambient air outside of the CCTU.

15 A CAS can include a controlled atmosphere unit (CAU) that is attached to a transport unit and is configured to control a temperature of a storage space of the CCTU. The CAU can include, without limitation, the air compressor, the CO<sub>2</sub> filter and the fresh air exchange mechanism.

20 In some embodiments, the CCTU can also include a transport refrigeration system (TRS). A TRS includes, for example, a refrigeration system for controlling the refrigeration of a storage space of the CCTU. The TRS may be a vapor-compressor type refrigeration system, a thermal accumulator type system, or any other suitable refrigeration system that can use refrigerant, cold plate technology, or the like.

25 A TRS can include a transport refrigeration unit (TRU) that is attached to a transport unit and is configured to control a temperature of a storage space of the CCTU. The TRU can include, without limitation, a compressor, a refrigerant condenser, a refrigerant expansion valve, a refrigerant evaporator, and one or more fans or blowers to control the heat exchange between the air within the storage space and the ambient air outside of the refrigerated transport unit.

In some embodiments, the TRU and the CAU can be the same unit (herein referred to as a controlled atmosphere and refrigeration unit (CARU)) that is attached to the transport unit. In

other embodiments, the TRU and the CAU can be separate units that are each attached to the transport unit.

It is to be appreciated that the embodiments disclosed herein is not limited to a transport unit, such as for example, a trailer (e.g., trailer on flat car, etc.), a container (e.g., container on  
5 flat cars, intermodal container, marine container, etc.), a truck, a box car, an air cargo cabin, etc. The embodiments disclosed herein can generally work with a storage space of such as, for example, a refrigeration unit, a cold room, etc.

Fig. 1 illustrates a CCTU 100 with which the embodiments disclosed herein can work. The CCTU 100 includes a CARU 120 attached to a transport unit 130. The CARU 120 is  
10 configured to control an atmosphere composition such as, for example, an oxygen concentration and/or a carbon dioxide concentration in the storage space 150. Also, the CARU 120 is configured to control a temperature in a storage space 150 of the transport unit 130.

The CCTU 100 includes one or more sensors (not shown) disposed within the storage space 150. The one or more sensors can be configured to monitor various environmental  
15 conditions within the storage space such as e.g., a temperature, a carbon dioxide concentration, an oxygen concentration, etc.

The CARU 120 and the one or more of the sensors can work together to provide a CAS that is configured to provide a desired atmosphere condition within the storage space 150. Also, the CARU 120 and the one or more of the sensors can work together to provide a TRS that is  
20 configured to provide a desired temperature condition within the storage space 150.

The CARU 120 also includes a programmable controller 135 that includes a single integrated control unit 140. The controller 135 is configured to monitor and control operation of the CAS and the TRS.

It is to be appreciated that, in some embodiments, the controller 135 may include a  
25 distributed network of control elements (not shown). The number of distributed control elements in a given network can depend upon the particular application of the principles described herein. The controller 135 can include a processor, a memory, a clock, and an input/output (I/O) interface (not shown). The controller 135 can include fewer or additional components.

Fig. 2 illustrates a schematic diagram of one configuration of a CAS 200 that is configured to provide atmosphere control in a storage space 205. The configuration of the CAS 200 shown in Fig. 2 is configured to operate an adsorption cycle and/or a desorption cycle with real time monitoring of a CO<sub>2</sub> filter 215.

5 The CAS 200 includes an air compressor 210, the CO<sub>2</sub> filter 215, a CO<sub>2</sub> sensor 220, a CO<sub>2</sub> and O<sub>2</sub> sensor 225, a fresh air exchange mechanism 230 and a controller 235. The CAS 200 also includes air flow control valves 240a, 240b to control air flow within the CAS 200.

In some embodiments, the CAS 200 is configured for a transport unit (e.g., the transport unit 130 shown in Fig. 1). Accordingly, in some embodiments, components of the CAS 200 including e.g., the air compressor 210, the CO<sub>2</sub> filter 215, the CO<sub>2</sub> and O<sub>2</sub> sensor 225, the fresh  
10 air exchange mechanism 230, the controller 235 and the air flow control valves 240a,b can be located within a CARU (e.g., the CARU 120 shown in Fig. 1).

The air compressor 210 is configured to receive air from the storage space 205, pressurize the air and direct the pressurized air to, for example, the CO<sub>2</sub> filter 215. The air  
15 compressor 210 is configured to operate based on instruction data received from the controller 235. In particular, the air compressor 210 can be instructed by the controller 235 to direct air from the storage space 205 and pressurized by the air compressor 210 to the CO<sub>2</sub> filter 215 (an adsorption state). Also, the air compressor 210 can be instructed by the controller 235 to direct air from the atmosphere and pressurized by the air compressor 210 to the CO<sub>2</sub> filter 215 (a  
20 desorption state). The controller 235 can also instruct the air compressor 210 to operate in an off state and/or a standby state. In some embodiments, the air compressor 210 can be a rotary vane air compressor that can provide low maintenance operation and can require minimum or no oil to operate.

The CO<sub>2</sub> filter 215 is configured to adsorb CO<sub>2</sub> from air directed from the air compressor  
25 210. In some embodiments, the CO<sub>2</sub> filter 215 can be an activated carbon filter. Particularly, in some embodiments, the CO<sub>2</sub> filter 215 can include an extruded activated carbon that is capable of regeneration.

The CO<sub>2</sub> sensor 220 is configured to be located, for example, near an exit of a CO<sub>2</sub> absorber (not shown) of the CO<sub>2</sub> filter 215 and is configured to monitor a CO<sub>2</sub> level of the CO<sub>2</sub> filter 215. In particular, the CO<sub>2</sub> sensor 220 is configured to monitor a CO<sub>2</sub> level of the activated carbon filter of the CO<sub>2</sub> filter 215 during the adsorption process. The CO<sub>2</sub> sensor 220 is also  
5 configured to send the monitored adsorption process activated carbon filter CO<sub>2</sub> level data of the CO<sub>2</sub> filter 215 to the controller 235.

The CO<sub>2</sub> and O<sub>2</sub> sensor 225 is configured to be located, for example, within an evaporator section (not shown) of the CARU and is configured to monitor a CO<sub>2</sub> level and an O<sub>2</sub> level within the storage space of the transport unit. The CO<sub>2</sub> and O<sub>2</sub> sensor 225 is also  
10 configured to send the monitored storage space CO<sub>2</sub> data and the monitored storage space O<sub>2</sub> data to the controller 235. While the CO<sub>2</sub> and O<sub>2</sub> sensor 225 is shown as a single component within the CAS 200, it will be appreciated that in some embodiments the CO<sub>2</sub> and O<sub>2</sub> sensor 225 can be made up of a combined CO<sub>2</sub> and O<sub>2</sub> sensor and in other embodiments the CO<sub>2</sub> and O<sub>2</sub> sensor 225 can be made of one or more CO<sub>2</sub> sensors and one or more O<sub>2</sub> sensors.

The fresh air control mechanism 230 is configured to allow air from the atmosphere (e.g., the outside ambient surrounding the outside of the transport unit) to enter the storage space 205. In some embodiments, the fresh air control mechanism 230 can be a damper configured to allow air from an ambient outside of the transport unit to enter a storage space in the transport unit. The fresh air control mechanism 230 is configured to operate based on instruction data received  
15 from the controller 235.  
20

The controller 235 is configured to monitor and control operation of the CAS 200. Particularly, the controller 235 is configured to receive the adsorption process activated carbon filter CO<sub>2</sub> level data from the CO<sub>2</sub> sensor 220 (via line 260a) and receive storage space CO<sub>2</sub> level data and storage space O<sub>2</sub> level data from the CO<sub>2</sub> and O<sub>2</sub> sensor 225 (via line 260b). The  
25 controller 235 is also configured to send instruction data to the air compressor 210 (via line 260c), the fresh air exchange mechanism 230 (via line 260d), and the air flow control valves 240a,b (via lines 260e,f). Communication between the controller 235 and the air compressor 210, the CO<sub>2</sub> filter 215, the CO<sub>2</sub> sensor 220, the CO<sub>2</sub> and O<sub>2</sub> sensor 225, the fresh air exchange

mechanism 230, and the air flow control valves 240a,b can be via one or more of a wireless connection (e.g., ZigBee, Bluetooth, WiFi, infrared, etc.) and a wired connection (e.g., USB, etc.).

In some embodiments, the controller 235 can also be configured to monitor and control operation of a TRS. The controller 235 can include a processor, a memory portion, a clock, and an input/output (I/O) interface (not shown).

The air flow control valves 240a,b are configured to direct air through the CAS 200. In particular, the air flow control valve 240a is configured to direct air from the CO<sub>2</sub> filter 215 (via the CO<sub>2</sub> sensor 220) to either the atmosphere (e.g., the outside ambient surrounding the outside of the transport unit) (e.g., during the desorption cycle) and/or the storage space 205 (e.g., during the adsorption cycle). The air flow control valve 240b is configured to direct air from either the storage space 205 (e.g., during the adsorption cycle) and/or the atmosphere (e.g., the outside ambient surrounding the outside of the transport unit) to the air compressor 210 (e.g., during the desorption cycle). The air flow control valves 240a,b are configured to operate based on instructions received from the controller 235. In some embodiments, the air flow control valves 240a,b can be three way valves. Also, in some embodiments, the air flow control valves 240a,b can be solenoid valves.

The configuration shown in Fig. 2 shows an adsorption cycle for filtering CO<sub>2</sub> out of air within the storage space 205 via line 250. The adsorption cycle begins by directing air from the storage space 205 to the air compressor 210 via the air flow control valve 240b. The air directed to the air compressor 210 is compressed and then directed to the CO<sub>2</sub> filter 215. The CO<sub>2</sub> filter 215 filters CO<sub>2</sub> from the compressed air via an adsorption process. After passing by the CO<sub>2</sub> sensor 220, the filtered air is sent back to the storage space 205 via the air flow control valve 240a.

The configuration shown in Fig. 2 also shows a desorption cycle for reactivating an activated carbon filter of the CO<sub>2</sub> filter when, for example, the activated carbon filter becomes saturated with CO<sub>2</sub>, via line 255. The desorption cycle begins by directing air from the atmosphere to the air compressor 210 via the air flow control valve 240b. In some embodiments,

the air from the atmosphere is hot air from a condenser of the CARU. The hot air directed to the air compressor 210 is compressed and then directed to the CO<sub>2</sub> filter 215. In other embodiments, the CAS 200 can include one or more heaters (e.g., one or more electrically operated heaters) (not shown) that are configured to heat air from the atmosphere before being directed to the CO<sub>2</sub> filter 215. The optional heaters can be provided upstream or downstream of the air compressor 210. In yet some other embodiments, the hot compressed air directed to the CO<sub>2</sub> filter 215 can be from hot air from the condenser and heated by the optional heater(s). The CO<sub>2</sub> in the activated carbon filter is removed from the CO<sub>2</sub> filter 215 by the compressed hot air via a desorption process. After passing by the CO<sub>2</sub> sensor 220, the air is sent back to the atmosphere via the air flow control valve 240a.

Fig. 3 illustrates a flowchart of a method 300 for operating the CAS 200 in the configuration shown in Fig. 2. At 305, the CO<sub>2</sub> sensor 220 monitors a CO<sub>2</sub> level of the CO<sub>2</sub> filter 215 during the adsorption process and sends the monitored adsorption process activated carbon filter CO<sub>2</sub> level data to the controller 235. At 310, the CO<sub>2</sub> and O<sub>2</sub> sensor 225 monitors a CO<sub>2</sub> level and an O<sub>2</sub> level within the storage space 205 of the transport unit and sends the monitored storage space CO<sub>2</sub> level and the monitored storage space O<sub>2</sub> level data to the controller 235.

At 315, the controller 235 stores the adsorption process activated carbon filter CO<sub>2</sub> level data, the storage space CO<sub>2</sub> level data, and the storage space O<sub>2</sub> level data in a memory portion of the controller 235. At 320, the controller 235 determines operation of the CAS 200 based on one or more of the adsorption process activated carbon filter CO<sub>2</sub> level data, the storage space CO<sub>2</sub> level data, and the storage space O<sub>2</sub> level data.

When the adsorption process activated carbon filter CO<sub>2</sub> level is greater than or equal to the storage space CO<sub>2</sub> level (325), the controller 235 stops the adsorption cycle (e.g., directing air through the line 250) and starts the desorption cycle (e.g., directing air through the line 255). In particular, the controller 235 instructs the air flow control valve 240b to stop directing air from the storage space 205 to the air compressor 210 and to start directing air from the atmosphere to the air compressor 210. The controller 235 also instructs the air flow control valve 240a to stop directing air from the CO<sub>2</sub> filter 215 (via the CO<sub>2</sub> sensor 220) to the storage space 205 and to

start directing air from the CO<sub>2</sub> filter 215 (via the CO<sub>2</sub> sensor 220) to the atmosphere. The controller 235 instructs the air compressor 210 to switch operation from the adsorption state to the desorption state. In some embodiments, the controller 435 can instruct any optional heaters that are configured to heat air for the desorption process to turn on.

- 5           When the storage space O<sub>2</sub> level is less than or equal to a low level oxygen threshold (330), the controller 235 instructs the fresh air control mechanism 230 to open and allow air from the atmosphere (e.g., the outside ambient surrounding the outside of the transport unit) to enter the storage space 205. In some embodiments, the controller 235 can control how far open the fresh air control mechanism 230 is to be opened based on the monitored storage space O<sub>2</sub> level.
- 10   The low level oxygen threshold can be a system or user defined value that can vary based on the type of transport unit in use, the type of cargo stored in the storage space 205, etc.

- When the storage space CO<sub>2</sub> level is greater than or equal to a high level storage space carbon dioxide threshold (335), the controller 235 starts the adsorption cycle (e.g., directing air through the line 250). In particular, the controller 235 instructs the air flow control valve 240b to
- 15   start directing air from the storage space 205 to the air compressor 210. The controller 235 also instructs the air flow control valve 240a to start directing air from the CO<sub>2</sub> filter 215 (via the CO<sub>2</sub> sensor 220) to the storage space 205. The controller 235 instructs the air compressor 210 to start operation at an adsorption state. The high level storage space carbon dioxide threshold can be a system or user defined value that can vary based on the type of transport unit in use, the type of
- 20   cargo stored in the storage space 205, etc.

- When the storage space CO<sub>2</sub> level is less than or equal to a low level storage space carbon dioxide threshold (340), the controller 235 stops the adsorption cycle (e.g., directing air through the line 250) and stops the desorption cycle (e.g., directing air through the line 255). In particular, the controller 235 instructs the air flow control valve 240b to stop directing air from
- 25   the storage space 205 to the air compressor 210 and to stop directing air from the atmosphere to the air compressor 210. The controller 235 also instructs the air flow control valve 240b to stop directing air from the CO<sub>2</sub> filter 215 (via the CO<sub>2</sub> sensor 220) to the storage space 205 and to stop directing air to the atmosphere. The controller 235 instructs the air compressor 210 to switch

operation from an adsorption state and/or desorption state to an off and/or standby state. In some embodiments, the controller 435 can instruct any optional heaters that are configured to heat air for the desorption process to turn off. The low level storage space carbon dioxide threshold can be a system or user defined value that can vary based on the type of transport unit in use, the type of cargo stored in the storage space 205, etc.

When the storage space  $O_2$  level is greater than or equal to a high level oxygen threshold (345), the controller 235 instructs the fresh air control mechanism 230 to close and prevent air from the atmosphere (e.g., the outside ambient surrounding the outside of the transport unit) to enter the storage space 205. In some embodiments, the controller 235 can control how far closed the fresh air control mechanism 230 is to be closed based on the monitored storage space  $O_2$  level. The high level oxygen threshold can be a system or user defined value that can vary based on the type of transport unit in use, the type of cargo stored in the storage space 205, etc.

When the adsorption process activated carbon filter  $CO_2$  level is less than or equal to a maximum level activated carbon filter threshold (350), the controller 235 starts the adsorption cycle (e.g., directing air through the line 250) and stops the desorption cycle (e.g., directing air through the line 255). In particular, the controller 235 instructs the air flow control valve 240b to start directing air from the storage space 205 to the air compressor 210 and to stop directing air from the atmosphere to the air compressor 210. The controller 235 also instructs the air flow control valve 240a to start directing air from the  $CO_2$  filter 215 (via the  $CO_2$  sensor 220) to the storage space 205 and to stop directing air from the  $CO_2$  filter 215 (via the  $CO_2$  sensor 220) to the atmosphere. The controller 235 instructs the air compressor 210 to switch operation from the desorption state to the adsorption state. In some embodiments, the controller 235 can instruct any optional heaters that are configured to heat air for the desorption process to turn off. In some embodiments, the maximum level activated carbon filter threshold can be, for example, ~.03%.

Fig. 4 illustrates a schematic diagram of another configuration of a CAS 400 that is configured to provide atmosphere control in the storage space 205. The configuration of the CAS 400 shown in Fig. 4 is configured to operate an adsorption cycle and/or a desorption cycle

with real time monitoring of a CO<sub>2</sub> filter 215. The CAS 400 is similar to the CAS 200 shown in Fig. 2. Differences between the CAS 400 from the CAS 200 are described below.

The CAS 400 does not include the air flow control valve 240a, but includes additional air flow control valves 240c,d,e. The air flow control valve 240c is configured to direct air from the air compressor 210 to either the air flow control valve 240d (e.g., during the adsorption cycle) and/or the flow control valve 240e (e.g., during the desorption cycle). The air flow control valve 240d is configured to direct air from the air flow control valve 240c to the CO<sub>2</sub> filter 215 (e.g., during the adsorption cycle), and to direct air from the CO<sub>2</sub> filter 215 to the atmosphere (via the CO<sub>2</sub> sensor 220) (e.g., during the desorption cycle). The air flow control valve 240e is configured to direct air from the CO<sub>2</sub> filter 215 to the storage space 205 (via the CO<sub>2</sub> sensor 220) (e.g., during the adsorption cycle), and to direct air from the air flow control valve 240c to the CO<sub>2</sub> filter 215 (e.g., during the desorption cycle). Like the air flow control valves 240a,b, the air flow control valves 240c,d,e are configured to operate based on instructions received from the controller 235. In some embodiments, the air flow control valves 240c,d,e can be three way valves. Also, in some embodiments, the air flow control valves 240c,d,e can be solenoid valves.

The controller 435 is configured to monitor and control operation of the CAS 400. Particularly, the controller 435 is configured to receive activated carbon filter CO<sub>2</sub> level data from the CO<sub>2</sub> sensor 220 (via lines 260a) and receive storage space CO<sub>2</sub> level data and storage space O<sub>2</sub> level data from the CO<sub>2</sub> and O<sub>2</sub> sensor 225 (via line 260b). The controller 435 is also configured to send instruction data to the air compressor 210 (via line 260c), the fresh air exchange mechanism 230 (via line 260d), and the air flow control valves 240b,c,d,e (via lines 260f,g,h,j). Communication between the controller 435 and the air compressor 210, the CO<sub>2</sub> filter 215, the CO<sub>2</sub> sensor 220, the CO<sub>2</sub> and O<sub>2</sub> sensor 225, the fresh air exchange mechanism 230, and the air flow control valves 240b,c,d,e can be via one or more of a wireless connection (e.g., ZigBee, Bluetooth, WiFi, infrared, etc.) and a wired connection (e.g., USB, etc.).

The configuration shown in Fig. 4 shows an adsorption cycle for filtering CO<sub>2</sub> out of air within the storage space 205 via line 450. The adsorption cycle begins by directing air from the storage space 205 to the air compressor 210 via the air flow control valve 240b. The air directed

to the air compressor 210 is compressed and then directed to the CO<sub>2</sub> filter 215 via the air flow control valves 240c and 240d. The CO<sub>2</sub> filter 215 filters CO<sub>2</sub> from the compressed air via an adsorption process. After passing through the air flow control valve 240e and passing by the CO<sub>2</sub> sensor 220, the filtered air is sent back to the storage space 205.

5           The configuration shown in Fig. 4 also shows a desorption cycle for reactivating an activated carbon filter of the CO<sub>2</sub> filter when, for example, the activated carbon filter becomes saturated with CO<sub>2</sub>, via line 455. The desorption cycle begins by directing air from the atmosphere to the air compressor 210 via the air flow control valve 240b. In some embodiments, the air from the atmosphere is hot air from a condenser of the CARU. The hot air directed to the  
10   air compressor 210 is compressed and then directed to the CO<sub>2</sub> filter 215 via the air flow control valves 240c,e. In other embodiments, the CAS 400 can include one or more heaters (e.g., one or more electrically operated heaters) (not shown) that are configured to heat air from the atmosphere before being directed to the CO<sub>2</sub> filter 215. The optional heaters can be provided upstream or downstream of the air compressor 210. In yet some other embodiments, the hot  
15   compressed air directed to the CO<sub>2</sub> filter 215 can be from hot air from the condenser and heated by the optional heater(s). The CO<sub>2</sub> in the activated carbon filter is removed from the CO<sub>2</sub> filter 215 by the compressed hot air via a desorption process. After passing through the air flow control valve 240d and passing by the CO<sub>2</sub> sensor 220, the air is sent back to the atmosphere.

Fig. 5 illustrates a flowchart of a method 500 for operating the CAS 400 in the  
20   configuration shown in Fig. 4. At 505, the CO<sub>2</sub> sensor 220 monitors a CO<sub>2</sub> level of the CO<sub>2</sub> filter 215 during the adsorption process and sends the monitored adsorption process activated carbon filter CO<sub>2</sub> level data to the controller 435. At 510, the CO<sub>2</sub> and O<sub>2</sub> sensor 225 monitors a CO<sub>2</sub> level and an O<sub>2</sub> level within the storage space 205 of the transport unit and sends the monitored storage space CO<sub>2</sub> level and the monitored storage space O<sub>2</sub> level data to the controller 235. At  
25   515, the CO<sub>2</sub> sensor 220 monitors a CO<sub>2</sub> level of the CO<sub>2</sub> filter 215 during the desorption process and sends the monitored desorption process activated carbon filter CO<sub>2</sub> level data to the controller 435.

At 520, the controller 435 stores the adsorption process activated carbon filter CO<sub>2</sub> level data, the storage space CO<sub>2</sub> level data, the storage space O<sub>2</sub> level data, and the desorption process activated carbon filter CO<sub>2</sub> level data in a memory portion of the controller 435. At 525, the controller 435 determines operation of the CAS 400 based on one or more of the adsorption process activated carbon filter CO<sub>2</sub> level data, the storage space CO<sub>2</sub> level data, the storage space O<sub>2</sub> level data, and the desorption process activated carbon filter CO<sub>2</sub> level data.

When the adsorption process activated carbon filter CO<sub>2</sub> level is greater than or equal to the storage space CO<sub>2</sub> level (530), the controller 435 stops the adsorption cycle (e.g., directing air through the line 450) and starts the desorption cycle (e.g., directing air through the line 455). In particular, the controller 435 instructs the air flow control valve 240b to stop directing air from the storage space 205 to the air compressor 210 and to start directing air from the atmosphere to the air compressor 210. The controller 435 also instructs the air flow control valve 240c to stop directing air from the air compressor 210 to the air flow control valve 240d and to start directing air from the air compressor 210 to the air flow control valve 240e. Also, the controller 435 instructs the air flow control valve 240d to stop directing air from the air flow control valve 240c to the CO<sub>2</sub> filter 215 and to start directing air from the CO<sub>2</sub> filter 215 to the atmosphere (via the CO<sub>2</sub> sensor 220). Further, the controller 435 instructs the air flow control valve 240e to stop directing air from the CO<sub>2</sub> filter 215 to the storage space 205 (via the CO<sub>2</sub> sensor 220) and to start directing air from the air flow control valve 240c to the CO<sub>2</sub> filter 215. The controller 435 instructs the air compressor 210 to switch operation from the adsorption state to the desorption state.

When the storage space O<sub>2</sub> level is greater than or equal to a low level oxygen threshold (535), the controller 435 instructs the fresh air control mechanism 230 to close and prevent air from the atmosphere (e.g., the outside ambient surrounding the outside of the transport unit) to enter the storage space 205. In some embodiments, the controller 435 can control how far closed the fresh air control mechanism 230 is to be closed based on the monitored storage space O<sub>2</sub> level. The high level oxygen threshold can be a system or user defined value that can vary based on the type of transport unit in use, the type of cargo stored in the storage space 205, etc.

When the storage space CO<sub>2</sub> level is greater than or equal to a high level storage space carbon dioxide threshold (540), the controller 435 starts the adsorption cycle (e.g., directing air through the line 450). In particular, the controller 435 instructs the air flow control valve 240b to start directing air from the storage space 205 to the air compressor 210. The controller 435 also  
5 instructs the air flow control valve 240c to start directing air from the air compressor 210 to the air flow control valve 240d. The controller 435 also instructs the air flow control valve 240d to start directing air from the air flow control valve 240c to the CO<sub>2</sub> filter 215. Also, the controller 435 instructs the air flow control valve 240e to start directing air from the CO<sub>2</sub> filter 215 to the storage space 205 (via the CO<sub>2</sub> sensor 220). The controller 435 instructs the air compressor 210  
10 to start operation at an adsorption state. The high level storage space carbon dioxide threshold can be a system or user defined value that can vary based on the type of transport unit in use, the type of cargo stored in the storage space 205, etc.

When the desorption process activated carbon filter CO<sub>2</sub> level is less than or equal to a maximum level activated carbon filter threshold (545), the controller 435 starts the adsorption  
15 cycle (e.g., directing air through the line 450) and stops the desorption cycle (e.g., directing air through the line 455). In particular, the controller 435 instructs the air flow control valve 240b to start directing air from the storage space 205 to the air compressor 210 and to stop directing air from the atmosphere to the air compressor 210. The controller 435 also instructs the air flow control valve 240c to start directing air from the air compressor 210 to the air flow control valve  
20 240d and to stop directing air from the air compressor 210 to the air flow control valve 240e. Also, the controller 435 instructs the air flow control valve 240d to start directing air from the air flow control valve 240c to the CO<sub>2</sub> filter 215 and to stop directing air from the CO<sub>2</sub> filter 215 to the atmosphere (via the CO<sub>2</sub> sensor 220). Further, the controller 435 instructs the air flow control valve 240e to start directing air from the CO<sub>2</sub> filter 215 to the storage space 205 (via the  
25 CO<sub>2</sub> sensor 220) and to stop directing air from the air flow control valve 240c to the CO<sub>2</sub> filter 215. The controller 435 instructs the air compressor 210 to switch operation from the desorption state to the adsorption state. In some embodiments, the controller 435 can instruct any optional

heaters that are configured to heat air for the desorption process to turn off. In some embodiments, the maximum level activated carbon filter threshold can be, for example, ~.03%.

When the storage space O<sub>2</sub> level is less than or equal to a low level oxygen threshold (550), the controller 435 instructs the fresh air control mechanism 230 to open and allow air from the atmosphere (e.g., the outside ambient surrounding the outside of the transport unit) to enter the storage space 205. In some embodiments, the controller 435 can control how far open the fresh air control mechanism 230 is to be opened based on the monitored storage space O<sub>2</sub> level. The low level oxygen threshold can be a system or user defined value that can vary based on the type of transport unit in use, the type of cargo stored in the storage space 205, etc.

When the adsorption process activated carbon filter CO<sub>2</sub> level is less than or equal to a low level activated carbon filter threshold (555), the controller 435 stops the adsorption cycle (e.g., directing air through the line 450) and stops the desorption cycle (e.g., directing air through the line 455). In particular, the controller 435 instructs the air flow control valve 240b to stop directing air from the storage space 205 to the air compressor 210 and to stop directing air from the atmosphere to the air compressor 210. The controller 435 also instructs the air flow control valve 240c to stop directing air from the air compressor 210 to the air flow control valve 240d and to stop directing air from the air compressor 210 to the air flow control valve 240e. Also, the controller 435 instructs the air flow control valve 240d to stop directing air from the air flow control valve 240c to the CO<sub>2</sub> filter 215 and to stop directing air from the CO<sub>2</sub> filter 215 to the atmosphere (via the CO<sub>2</sub> sensor 220). Further, the controller 435 instructs the air flow control valve 240e to stop directing air from the CO<sub>2</sub> filter 215 to the storage space 205 (via the CO<sub>2</sub> sensor 220) and to stop directing air from the air flow control valve 240c to the CO<sub>2</sub> filter 215. The controller 435 instructs the air compressor 210 to switch operation from an adsorption state and/or desorption state to an off and/or standby state. In some embodiments, the controller 435 can instruct any optional heaters that are configured to heat air for the desorption process to turn off. The low level CO<sub>2</sub> level threshold can be a system or user defined value that can vary based on the type of transport unit in use, the type of cargo stored in the storage space 205, etc.

Fig. 6 illustrates a schematic diagram of another configuration of a CAS 600 that is configured to provide atmosphere control in the storage space 205. The configuration of the CAS 600 shown in Fig. 6 is configured to operate an adsorption cycle with a fixed interval monitoring of the CO<sub>2</sub> filter 215. The CAS 600 is similar to the CAS 400 shown in Fig. 4.

5 Differences between the CAS 600 from the CASs 200,400 are described below. The CAS 600 can include the desorption cycle (e.g., as shown by line 455 in Fig. 4). However, for clarity, the desorption process is not shown.

The CAS 600 replaces the CO<sub>2</sub> sensor 220 with a CO<sub>2</sub> and O<sub>2</sub> sensor 625 and includes an intermittent cycle (shown by line 665) to provide fixed interval monitoring of the CO<sub>2</sub> filter 215.

10 The CO<sub>2</sub> and O<sub>2</sub> sensor 625 is configured to be located, for example, near an exit of a CO<sub>2</sub> absorber (not shown) of the CO<sub>2</sub> filter 215 and is configured to monitor a CO<sub>2</sub> level and an O<sub>2</sub> level of the CO<sub>2</sub> filter 215 during the absorption process and is configured to monitor a CO<sub>2</sub> level and an O<sub>2</sub> level within the storage space 205 during the intermittent process. The CO<sub>2</sub> and O<sub>2</sub> sensor 625 is also configured to send the monitored activated carbon filter CO<sub>2</sub> level data and  
15 the activated carbon filter O<sub>2</sub> level data of the CO<sub>2</sub> filter 215 and the monitored storage space CO<sub>2</sub> level data and the storage space O<sub>2</sub> level data of the storage space 205 to the controller 635. While the CO<sub>2</sub> and O<sub>2</sub> sensor 625 is shown as a single component within the CAS 600, it will be appreciated that in some embodiments the CO<sub>2</sub> and O<sub>2</sub> sensor 625 can be made up of a combined CO<sub>2</sub> and O<sub>2</sub> sensor and in other embodiments the CO<sub>2</sub> and O<sub>2</sub> sensor 625 can be made of one or  
20 more CO<sub>2</sub> sensors and one or more O<sub>2</sub> sensors.

In this configuration, the air flow control valve 240c is configured to direct air from the air compressor 210 to either the air flow control valve 240d (e.g., during the adsorption cycle) and/or the flow control valve 240e (e.g., during the intermittent cycle). The air flow control valve 240d is configured to direct air from the air flow control valve 240c to the CO<sub>2</sub> filter 215  
25 (e.g., during the adsorption cycle). The air flow control valve 240e is configured to direct air from the CO<sub>2</sub> filter 215 to the storage space 205 (via the CO<sub>2</sub> sensor 220) (e.g., during the adsorption cycle), and to direct air from the air flow control valve 240c to the storage space 205 (via the CO<sub>2</sub> sensor 220) (e.g., during the intermittent cycle).

The controller 635 is configured to monitor and control operation of the CAS 600. Particularly, the controller 635 is configured to receive the activated carbon filter CO<sub>2</sub> level data, the activated carbon filter O<sub>2</sub> level data, the storage space CO<sub>2</sub> level data, the storage space O<sub>2</sub> level data from the CO<sub>2</sub> and O<sub>2</sub> sensor 225 (via line 260b). The controller 635 is also configured to send instruction data to the air compressor 210 (via line 260c), the fresh air exchange mechanism 230 (via line 260d), and the air flow control valves 240b,c,d,e (via lines 260f,g,h,j). Communication between the controller 635 and the air compressor 210, the CO<sub>2</sub> filter 215, the CO<sub>2</sub> and O<sub>2</sub> sensor 225, the fresh air exchange mechanism 230, and the air flow control valves 240b,c,d,e can be via one or more of a wireless connection (e.g., ZigBee, Bluetooth, WiFi, infrared, etc.) and a wired connection (e.g., USB, etc.).

The configuration shown in Fig. 6 shows an adsorption cycle for filtering CO<sub>2</sub> out of air within the storage space 205 via line 650. The adsorption cycle begins by directing air from the storage space 205 to the air compressor 210 via the air flow control valve 240b. The air directed to the air compressor 210 is compressed and then directed to the CO<sub>2</sub> filter 215 via the air flow control valves 240c and 240d. The CO<sub>2</sub> filter 215 filters CO<sub>2</sub> from the compressed air via an adsorption process. After passing through the air flow control valve 240e and passing by the CO<sub>2</sub> and O<sub>2</sub> sensor 625, the filtered air is sent back to the storage space 205.

The configuration shown in Fig. 6 also shows an intermittent cycle intermittent monitoring of the adsorption cycle. The intermittent cycle begins by directing air from the storage space 205 to the air compressor 210 via the air flow control valve 240b. The air directed to the air compressor 210 is then directed to air flow control valve 240c and then to the air flow control valve 240e. After passing through the air flow control valve 240e and passing by the CO<sub>2</sub> and O<sub>2</sub> sensor 625, the air is sent back to the storage space 205.

Fig. 7 illustrates a flowchart of a method 700 for operating the CAS 600 in the configuration shown in Fig. 6. At 705, the CO<sub>2</sub> and O<sub>2</sub> sensor 625 monitors a CO<sub>2</sub> level and an O<sub>2</sub> level of the CO<sub>2</sub> filter 215 during the adsorption process and sends the monitored activated carbon filter CO<sub>2</sub> level data and the activated carbon filter O<sub>2</sub> level data to the controller 635.

At 710, the controller 635 stores the activated carbon filter CO<sub>2</sub> level data and the activated carbon filter O<sub>2</sub> level data in a memory portion of the controller 635. At 715, the controller 635 determines whether the activated carbon filter CO<sub>2</sub> level data is greater than or equal to a high level carbon dioxide threshold. If the controller 635 determines that the activated carbon filter CO<sub>2</sub> level data is greater than or equal to the high level carbon dioxide threshold, the method 700 proceeds to 720. If the controller 635 determines that the activated carbon filter CO<sub>2</sub> level data is less than the low level carbon dioxide threshold, the method 700 proceeds to 725. The high level carbon dioxide threshold can be a system or user defined value that can vary based on the type of transport unit in use, the type of cargo stored in the storage space 205, etc. The low level carbon dioxide threshold can be a system or user defined value that can vary based on the type of transport unit in use, the type of cargo stored in the storage space 205, etc.

At 720, the controller 635 instructs the CAS 600 to run in the adsorption cycle (e.g., directing air through the line 450) for at time period T<sub>1</sub>. In particular, the controller 635 instructs the air flow control valve 240b to start directing air from the storage space 205 to the air compressor 210. The controller 635 also instructs the air flow control valve 240c to start directing air from the air compressor 210 to the air flow control valve 240d. The controller 635 also instructs the air flow control valve 240d to start directing air from the air flow control valve 240c to the CO<sub>2</sub> filter 215. Also, the controller 635 instructs the air flow control valve 240e to start directing air from the CO<sub>2</sub> filter 215 to the storage space 205 (via the CO<sub>2</sub> and O<sub>2</sub> sensor 625). The controller 635 instructs the air compressor 210 to start operation at an adsorption state. The time period T<sub>1</sub> can be a system or user defined value that can vary based on the type of transport unit in use, the type of cargo stored in the storage space 205, etc. In some embodiments, the time period T<sub>1</sub> can be, for example, ~ 30 minutes.

The controller 635 also monitors and stores the activated carbon filter CO<sub>2</sub> level data during the time period T<sub>1</sub>. The method 700 then proceeds to 730.

At 730, the controller 635 instructs the CAS 600 to run in the intermittent cycle (e.g., directing air through the line 665) for at time period T<sub>2</sub>. In particular, the controller 635 instructs the air flow control valve 240b to start directing air from the storage space 205 to the air

compressor 210. The controller 635 also instructs the air flow control valve 240c to start directing air from the air compressor 210 to the air flow control valve 240e. The controller 635 also instructs the air flow control valve 240e to start directing air from the air flow control valve 240c to the storage space 205 (via the CO<sub>2</sub> and O<sub>2</sub> sensor 625). The controller 635 instructs the  
5 air compressor 210 to start operation at an intermittent cycle state. The time period T<sub>2</sub> can be a system or user defined value that can vary based on the type of transport unit in use, the type of cargo stored in the storage space 205, etc. In some embodiments, the time period T<sub>2</sub> can be, for example, ~ 5 minutes.

The controller 635 also monitors and stores the storage space CO<sub>2</sub> level data during the  
10 time period T<sub>2</sub>. The method 700 then proceeds to 735.

At 735, the controller 634 determines the operation of the CAS 600 based on the activated carbon filter CO<sub>2</sub> level data and the activated carbon filter O<sub>2</sub> level data. When the activated carbon filter CO<sub>2</sub> level data determined at 705 is less than or equal to the low level carbon dioxide threshold, the method 700 proceeds to 725. When the activated carbon filter CO<sub>2</sub>  
15 level data determined at 705 is greater than or equal to the high level carbon dioxide threshold and the activated carbon filter CO<sub>2</sub> level data determined at 720 is less than the storage space activated carbon filter CO<sub>2</sub> level data determined at 730, the method 700 proceeds back to 720. When the activated carbon filter CO<sub>2</sub> level data determined at 720 is greater than or equal to the storage space activated carbon filter CO<sub>2</sub> level data determined at 730, the method 700 proceeds  
20 to 740.

At 725, the controller 635 stops the adsorption cycle (e.g., directing air through the line 450). In particular, the controller 635 instructs the air flow control valve 240b to stop directing air from the storage space 205 to the air compressor 210. The controller 635 also instructs the air flow control valve 240c to stop directing air from the air compressor 210 to the air flow control  
25 valve 240d. Also, the controller 635 instructs the air flow control valve 240d to stop directing air from the air flow control valve 240c to the CO<sub>2</sub> filter 215. Further, the controller 635 instructs the air flow control valve 240e to stop directing air from the CO<sub>2</sub> filter 215 to the storage space

205 (via the CO<sub>2</sub> and O<sub>2</sub> sensor 625). The controller 635 instructs the air compressor 210 to switch operation from an adsorption state and/or desorption state to an off and/or standby state.

At 740, the controller 635 stops the adsorption cycle (e.g., directing air through the line 450) and starts the desorption cycle (e.g., directing air through the line 455 as shown in Fig. 4).

5 In particular, the controller 635 instructs the air flow control valve 240b to stop directing air from the storage space 205 to the air compressor 210 and to start directing air from the atmosphere to the air compressor 210. The controller 435 also instructs the air flow control valve 240c to stop directing air from the air compressor 210 to the air flow control valve 240d and to start directing air from the air compressor 210 to the air flow control valve 240e. Also,  
10 the controller 635 instructs the air flow control valve 240d to stop directing air from the air flow control valve 240c to the CO<sub>2</sub> filter 215 and to start directing air from the CO<sub>2</sub> filter 215 to the atmosphere (via the CO<sub>2</sub> and O<sub>2</sub> sensor 625). Further, the controller 635 instructs the air flow control valve 240e to stop directing air from the CO<sub>2</sub> filter 215 to the storage space 205 (via the CO<sub>2</sub> and O<sub>2</sub> sensor 625) and to start directing air from the air flow control valve 240c to the CO<sub>2</sub>  
15 filter 215. The controller 635 instructs the air compressor 210 to switch operation from the adsorption state to the desorption state.

Fig. 8 illustrates a flowchart of a method 800 for operating a CAS (e.g., the CASs 200, 400, 600 shown in Figs. 2, 4 and 6) based on a respiration profile of cargo stored within a storage space of the transport unit. In particular, a controller of the CAS (e.g., the controller 235, 435,  
20 635 shown in Figs. 2, 4 and 6) can be configured to store respiration profiles of different cargo (e.g., fruits such as bananas, strawberries, apples, etc.; vegetables such as lettuce, beets, broccoli, etc.; vegetation such as flowers, plants, herbs, etc.). The controller can then instruct the CAS to run adsorption and desorption cycles based on the respiration profile of the cargo stored in the storage space.

25 The method 800 begins at 805, whereby a respiration profile of a cargo to be stored in the storage space of the CAS is retrieved by the controller. In some embodiments, the respiration profile is stored in a memory portion of the controller and is selected (e.g., via a human machine interface) by a CAS operator for retrieval by the controller. In other embodiments, the

respiration profile can be sent to the controller, for example, from an external operator device (e.g. a smart phone, tablet, third party device, etc.), from a control center, etc. via a wired or wireless connection.

At 810, a CO<sub>2</sub> and O<sub>2</sub> sensor of the CAS (e.g., the CO<sub>2</sub> and O<sub>2</sub> sensor 225, 625 shown in Figs. 2, 4 and 6) monitors a CO<sub>2</sub> level and an O<sub>2</sub> level within the storage space of the transport unit and sends the monitored storage space CO<sub>2</sub> level and the monitored storage space O<sub>2</sub> level data to the controller.

At 815, the controller stores the the storage space CO<sub>2</sub> level data and the storage space O<sub>2</sub> level data in a memory portion of the controller. At 820, the controller determines operation of the CAS based on one or more of the storage space CO<sub>2</sub> level data, the storage space O<sub>2</sub> level data, and the respiration profile of the cargo stored in the storage space.

When the storage space O<sub>2</sub> level is greater than or equal to a high level oxygen threshold (825), the controller instructs a fresh air control mechanism (e.g., the fresh air control mechanism 230 shown in Figs. 2, 4 and 6) to close and prevent air from the atmosphere (e.g., the outside ambient surrounding the outside of the transport unit) to enter the storage space. In some embodiments, the controller can control how far closed the fresh air control mechanism is to be closed based on the monitored storage space O<sub>2</sub> level. The high level oxygen threshold can be defined in the respiration profile or can be a system or user defined value that can vary based on the type of transport unit in use, the type of cargo stored in the storage space, etc.

When the storage space CO<sub>2</sub> level is greater than or equal to a high level storage space carbon dioxide threshold (830), the controller starts the adsorption cycle for a time period T<sub>3</sub> determined in the respiration profile. At 835, the controller stops the adsorption cycle and starts the desorption cycle. The controller will run the desorption cycle for a time period T<sub>4</sub> determined in the respiration profile. The controller will continue cycle between running the adsorption cycle for the time period T<sub>3</sub> and the desorption cycle for the time period T<sub>4</sub> until the controller receives storage space CO<sub>2</sub> level data from the CO<sub>2</sub> and O<sub>2</sub> sensor that has a value about equal to a low level carbon dioxide threshold (840). The low level carbon dioxide threshold can be defined in the respiration profile or can be a system or user defined value that

can vary based on the type of transport unit in use, the type of cargo stored in the storage space, etc.

When the storage space O<sub>2</sub> level is less than or equal to a low level oxygen threshold (845), the controller instructs the fresh air control mechanism to open and allow air from the atmosphere (e.g., the outside ambient surrounding the outside of the transport unit) to enter the storage space. In some embodiments, the controller can control how far open the fresh air control mechanism is to be opened based on the monitored storage space O<sub>2</sub> level. The low level oxygen threshold can be defined in the respiration profile or can be a system or user defined value that can vary based on the type of transport unit in use, the type of cargo stored in the storage space, etc.

When the storage space CO<sub>2</sub> level is less than or equal to a low level storage space carbon dioxide threshold (850), the controller stops the adsorption cycle and stops the desorption cycle. The low level storage space carbon dioxide threshold can be defined in the respiration profile or can be a system or user defined value that can vary based on the type of transport unit in use, the type of cargo stored in the storage space, etc.

Accordingly, the embodiments described herein can provided continuous control of CO<sub>2</sub> and O<sub>2</sub> levels within a storage space of a transport unit by, for example, regenerating an activated carbon filter of a CO<sub>2</sub> filter when the activated carbon filter is at or near a saturation point and may no longer be able to absorb CO<sub>2</sub>.

## ASPECTS

It is noted that any of aspects 1 – 8 below can be combined with any of aspects 9-16.

Aspect 1. A controlled atmosphere system for controlling an atmosphere within a storage space, the system comprising:

an air compressor configured to pressurize air from at least one of the storage space and an ambient outside the storage space;

a carbon dioxide filter configured to receive pressurized air from the air compressor and configured to adsorb carbon dioxide from the storage space during an adsorption cycle and

configured desorb carbon dioxide out of the carbon dioxide filter into the ambient during a desorption cycle;

a carbon dioxide filter sensor configured to monitor a filter carbon dioxide level of the carbon dioxide filter and send filter carbon dioxide level data to a controller;

5 a carbon dioxide sensor configured to monitor a storage space carbon dioxide level of the storage space and send storage space carbon dioxide level data to the controller;

an oxygen sensor configured to monitor a storage space oxygen level of the storage space and send storage space oxygen level data to the controller;

10 the controller configured to receive filter carbon dioxide level data from the carbon dioxide filter sensor, receive storage space carbon dioxide level data from the carbon dioxide sensor, receive storage space oxygen level data from the oxygen sensor, and operate the system in the adsorption cycle and the desorption cycle based on one or more of the filter carbon dioxide level data, storage space carbon dioxide level data, and the storage space oxygen level data.

15 Aspect 2. The system of aspect 1, wherein the carbon dioxide filter includes an activated carbon filter.

Aspect 3. The system of any one of aspects 1-2, wherein the controller is configured to operate the system in the adsorption cycle when the storage space carbon dioxide level is greater  
20 than or equal to a high level storage space carbon dioxide threshold.

Aspect 4. The system of any one of aspects 1-3, wherein the controller is configured to operate the system in the adsorption cycle when the filter carbon dioxide level is less than or equal to a maximum level carbon level threshold.

25 Aspect 5. The system of any one of aspects 1-4, wherein the controller is configured to operate the system in the desorption cycle when filter carbon dioxide level is greater than or equal to the storage space carbon dioxide level.

Aspect 6. The system of any one of aspects 1-5, further comprising a fresh air exchange mechanism configured to allow air from the ambient to enter the storage space,

wherein the controller is configured to open the fresh air exchange mechanism when the storage space oxygen level is less than or equal to a low level oxygen threshold, and

5 wherein the controller is configured to close the fresh air exchange mechanism when the storage space oxygen level is greater than or equal to a high level oxygen threshold.

Aspect 7. The system of any one of aspects 1-6, wherein the controller is configured to

monitor one or more of the filter carbon dioxide level, the storage space carbon dioxide level and

10 the storage space oxygen level in real time, and configured to operate the system in an adsorption cycle and a desorption cycle in real time.

Aspect 8. The system of any one of aspects 1-6, wherein the controller is configured to

monitor one or more of the filter carbon dioxide level, the storage space carbon dioxide level and

15 the storage space oxygen level at intermittent time intervals, and configured to operate the system in an adsorption cycle and a desorption cycle at intermittent time intervals.

Aspect 9. A method for controlling an atmosphere within a storage space comprising:

pressurizing air from at least one of the storage space and an ambient outside the storage

20 space using an air compressor;

a carbon dioxide filter receiving pressurized air from the air compressor and adsorbing carbon dioxide from the storage space during an adsorption cycle and desorbing carbon dioxide out of the carbon dioxide filter into the ambient during a desorption cycle;

monitoring a filter carbon dioxide level of the carbon dioxide filter and sending filter

25 carbon dioxide level data to a controller;

monitoring a storage space carbon dioxide level of the storage space and sending storage space carbon dioxide level data to the controller;

monitoring a storage space oxygen level of the storage space and sending storage space

oxygen level data to the controller;

the controller receiving filter carbon dioxide level data, storage space carbon dioxide level data, and receiving storage space oxygen level data from the oxygen sensor;

the controller operating the system in the adsorption cycle and the desorption cycle based  
5 on one or more of the filter carbon dioxide level data, storage space carbon dioxide level data, and the storage space oxygen level data.

Aspect 10. The method of aspect 9, further comprising directing the pressurized air from the compressor to an activated carbon filter of the carbon dioxide filter.

10

Aspect 11. The method of any one of aspects 9-10, further comprising the controller operating the system in the adsorption cycle when the storage space carbon dioxide level is greater than or equal to a high level storage space carbon dioxide threshold.

15 Aspect 12. The method of any one of aspects 9-11, further comprising the controller operating the system in the adsorption cycle when the filter carbon dioxide level is less than or equal to a maximum level carbon level threshold.

Aspect 13. The method of any one of aspects 9-12, further comprising the controller  
20 operating the system in the desorption cycle when filter carbon dioxide level is greater than or equal to the storage space carbon dioxide level.

Aspect 14. The method of any one of aspects 9-13, further comprising the controller opening a fresh air exchange mechanism when the storage space oxygen level is less than or equal to a  
25 low level oxygen threshold, and

the controller closing the fresh air exchange mechanism when the storage space oxygen level is greater than or equal to a high level oxygen threshold.

Aspect 15. The method of any one of aspects 9-14, further comprising the controller monitoring one or more of the filter carbon dioxide level, the storage space carbon dioxide level and the storage space oxygen level in real time, and  
operating the system in an adsorption cycle and a desorption cycle in real time.

5

Aspect 16. The method of any one of aspects 9-14, further comprising the controller monitoring one or more of the filter carbon dioxide level, the storage space carbon dioxide level and the storage space oxygen level at intermittent time intervals, and  
operating the system in an adsorption cycle and a desorption cycle at intermittent time

10 intervals.

The terminology used in this Specification is intended to describe particular embodiments and is not intended to be limiting. The terms “a,” “an,” and “the” include the plural forms as well, unless clearly indicated otherwise. The terms “comprises” and/or “comprising,” when used  
15 in this Specification, specify the presence of the stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, and/or components.

With regard to the preceding description, it is to be understood that changes may be made in detail, especially in matters of the construction materials employed and the shape, size, and  
20 arrangement of parts without departing from the scope of the present disclosure. The word “embodiment” as used within this Specification may, but does not necessarily, refer to the same embodiment. This Specification and the embodiments described are exemplary only. Other and further embodiments may be devised without departing from the basic scope thereof, with the true scope and spirit of the disclosure being indicated by the claims that follow.

## CLAIMS

1. A controlled atmosphere system for controlling an atmosphere within a storage space, the system comprising:

an air compressor configured to pressurize air from at least one of the storage space and

5 an ambient outside the storage space;

a carbon dioxide filter configured to receive pressurized air from the air compressor and configured to adsorb carbon dioxide from the storage space during an adsorption cycle and configured desorb carbon dioxide out of the carbon dioxide filter into the ambient during a desorption cycle;

10 a carbon dioxide filter sensor configured to monitor a filter carbon dioxide level of the carbon dioxide filter and send filter carbon dioxide level data to a controller;

a carbon dioxide sensor configured to monitor a storage space carbon dioxide level of the storage space and send storage space carbon dioxide level data to the controller;

15 an oxygen sensor configured to monitor a storage space oxygen level of the storage space and send storage space oxygen level data to the controller;

the controller configured to receive filter carbon dioxide level data from the carbon dioxide filter sensor, receive storage space carbon dioxide level data from the carbon dioxide sensor, receive storage space oxygen level data from the oxygen sensor, and operate the system in the adsorption cycle and the desorption cycle based on one or more of the filter carbon dioxide level data, storage space carbon dioxide level data, and the storage space oxygen level data.

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2. The system of claim 1, wherein the carbon dioxide filter includes an activated carbon filter.

25 3. The system of claim 1, wherein the controller is configured to operate the system in the adsorption cycle when the storage space carbon dioxide level is greater than or equal to a high level storage space carbon dioxide threshold.

4. The system of claim 1, wherein the controller is configured to operate the system in the adsorption cycle when the filter carbon dioxide level is less than or equal to a maximum level carbon level threshold.

5. The system of claim 1, wherein the controller is configured to operate the system in the desorption cycle when filter carbon dioxide level is greater than or equal to the storage space carbon dioxide level.

6. The system of claim 1, further comprising a fresh air exchange mechanism configured to allow air from the ambient to enter the storage space,

wherein the controller is configured to open the fresh air exchange mechanism when the storage space oxygen level is less than or equal to a low level oxygen threshold, and

wherein the controller is configured to close the fresh air exchange mechanism when the storage space oxygen level is greater than or equal to a high level oxygen threshold.

7. The system of claim 1, wherein the controller is configured to monitor one or more of the filter carbon dioxide level, the storage space carbon dioxide level and the storage space oxygen level in real time, and configured to operate the system in an adsorption cycle and a desorption cycle in real time.

8. The system of claim 1, wherein the controller is configured to monitor one or more of the filter carbon dioxide level, the storage space carbon dioxide level and the storage space oxygen level at intermittent time intervals, and configured to operate the system in an adsorption cycle and a desorption cycle at intermittent time intervals.

9. A method for controlling an atmosphere within a storage space comprising:  
pressurizing air from at least one of the storage space and an ambient outside the storage space using an air compressor;

a carbon dioxide filter receiving pressurized air from the air compressor and adsorbing carbon dioxide from the storage space during an adsorption cycle and desorbing carbon dioxide out of the carbon dioxide filter into the ambient during a desorption cycle;

5 monitoring a filter carbon dioxide level of the carbon dioxide filter and sending filter carbon dioxide level data to a controller;

monitoring a storage space carbon dioxide level of the storage space and sending storage space carbon dioxide level data to the controller;

monitoring a storage space oxygen level of the storage space and sending storage space oxygen level data to the controller;

10 the controller receiving filter carbon dioxide level data, storage space carbon dioxide level data, and receiving storage space oxygen level data from the oxygen sensor;

the controller operating the system in the adsorption cycle and the desorption cycle based on one or more of the filter carbon dioxide level data, storage space carbon dioxide level data, and the storage space oxygen level data.

15

10. The method of claim 9, further comprising directing the pressurized air from the compressor to an activated carbon filter of the carbon dioxide filter.

11. The method of claim 9, further comprising the controller operating the system in the  
20 adsorption cycle when the storage space carbon dioxide level is greater than or equal to a high level storage space carbon dioxide threshold.

12. The method of claim 9, further comprising the controller operating the system in the  
25 adsorption cycle when the filter carbon dioxide level is less than or equal to a maximum level carbon level threshold.

13. The method of claim 9, further comprising the controller operating the system in the desorption cycle when filter carbon dioxide level is greater than or equal to the storage space

carbon dioxide level.

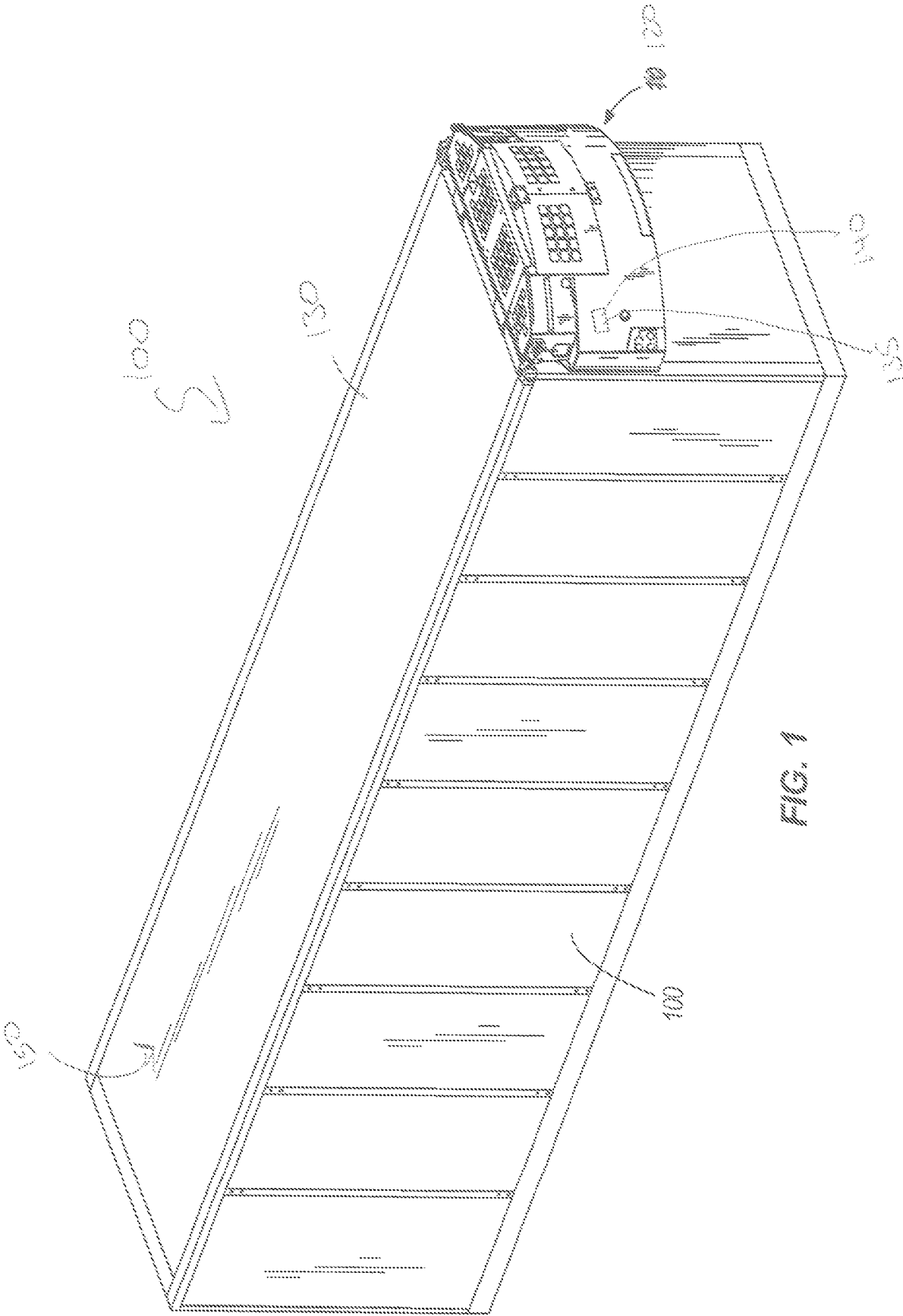
14. The method of claim 9, further comprising the controller opening a fresh air exchange mechanism when the storage space oxygen level is less than or equal to a low level oxygen  
5 threshold, and

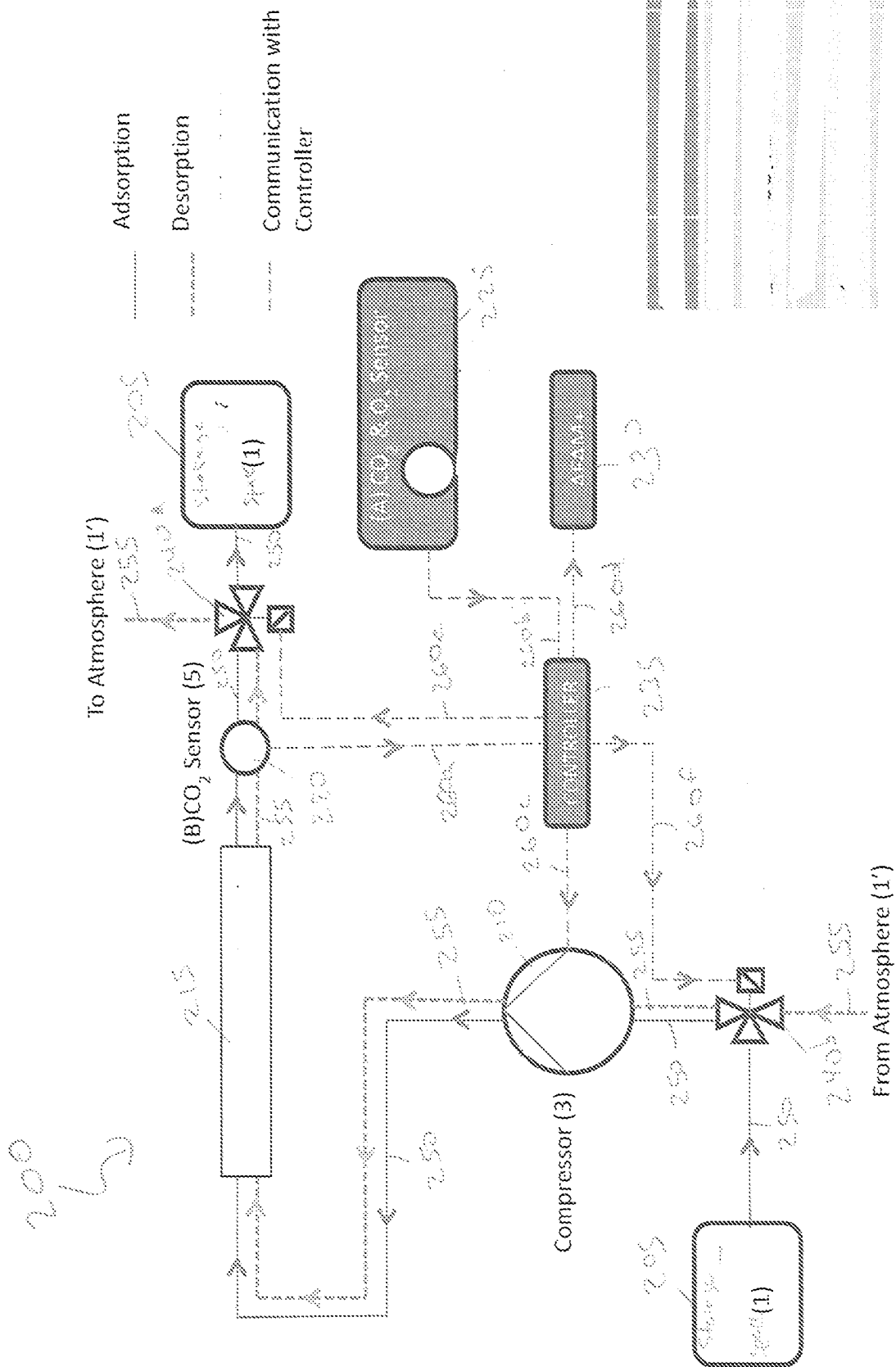
the controller closing the fresh air exchange mechanism when the storage space oxygen level is greater than or equal to a high level oxygen threshold.

15. The method of claim 9, further comprising the controller monitoring one or more of the  
10 filter carbon dioxide level, the storage space carbon dioxide level and the storage space oxygen level in real time, and  
operating the system in an adsorption cycle and a desorption cycle in real time.

16. The method of claim 9, further comprising the controller monitoring one or more of the  
15 filter carbon dioxide level, the storage space carbon dioxide level and the storage space oxygen level at intermittent time intervals, and  
operating the system in an adsorption cycle and a desorption cycle at intermittent time intervals.

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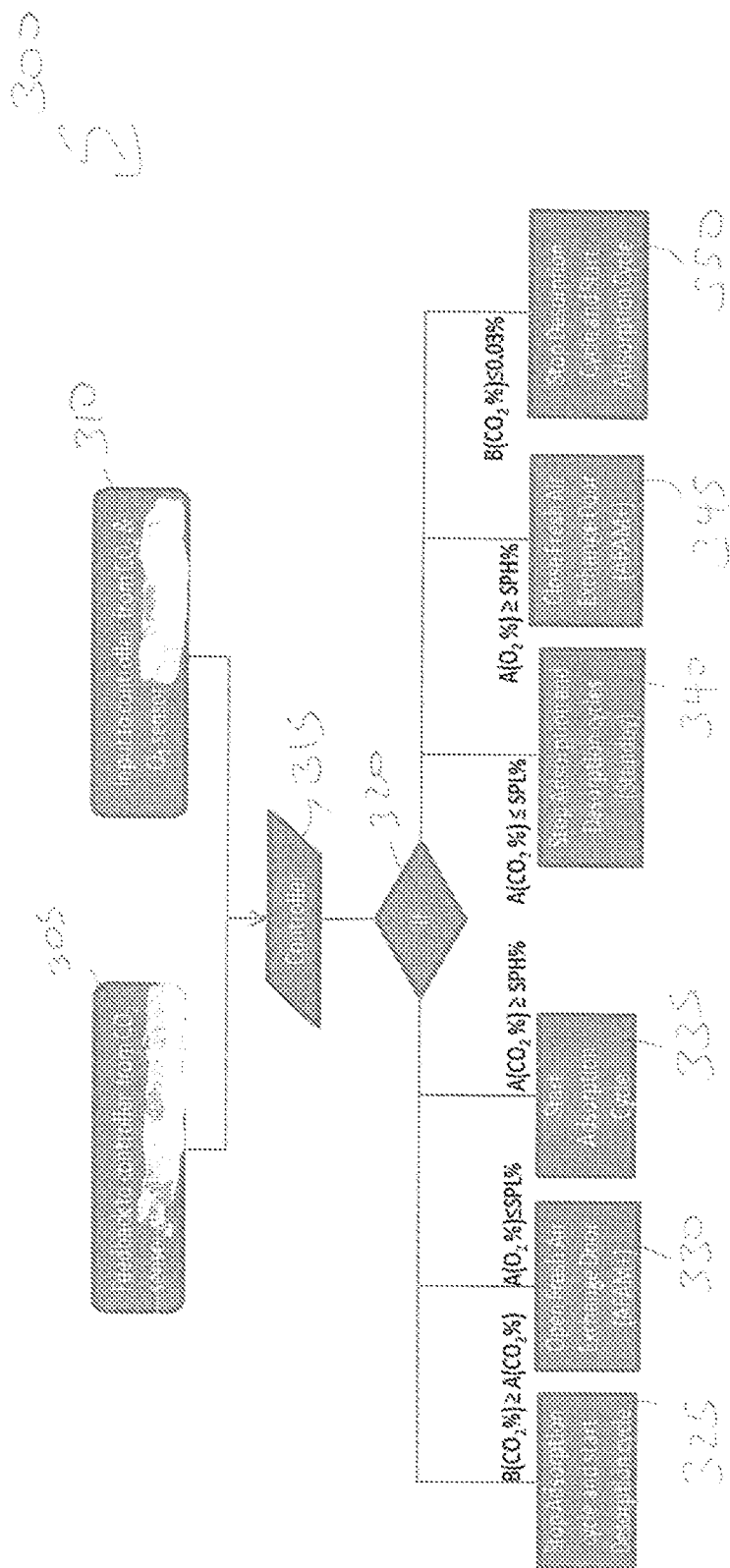
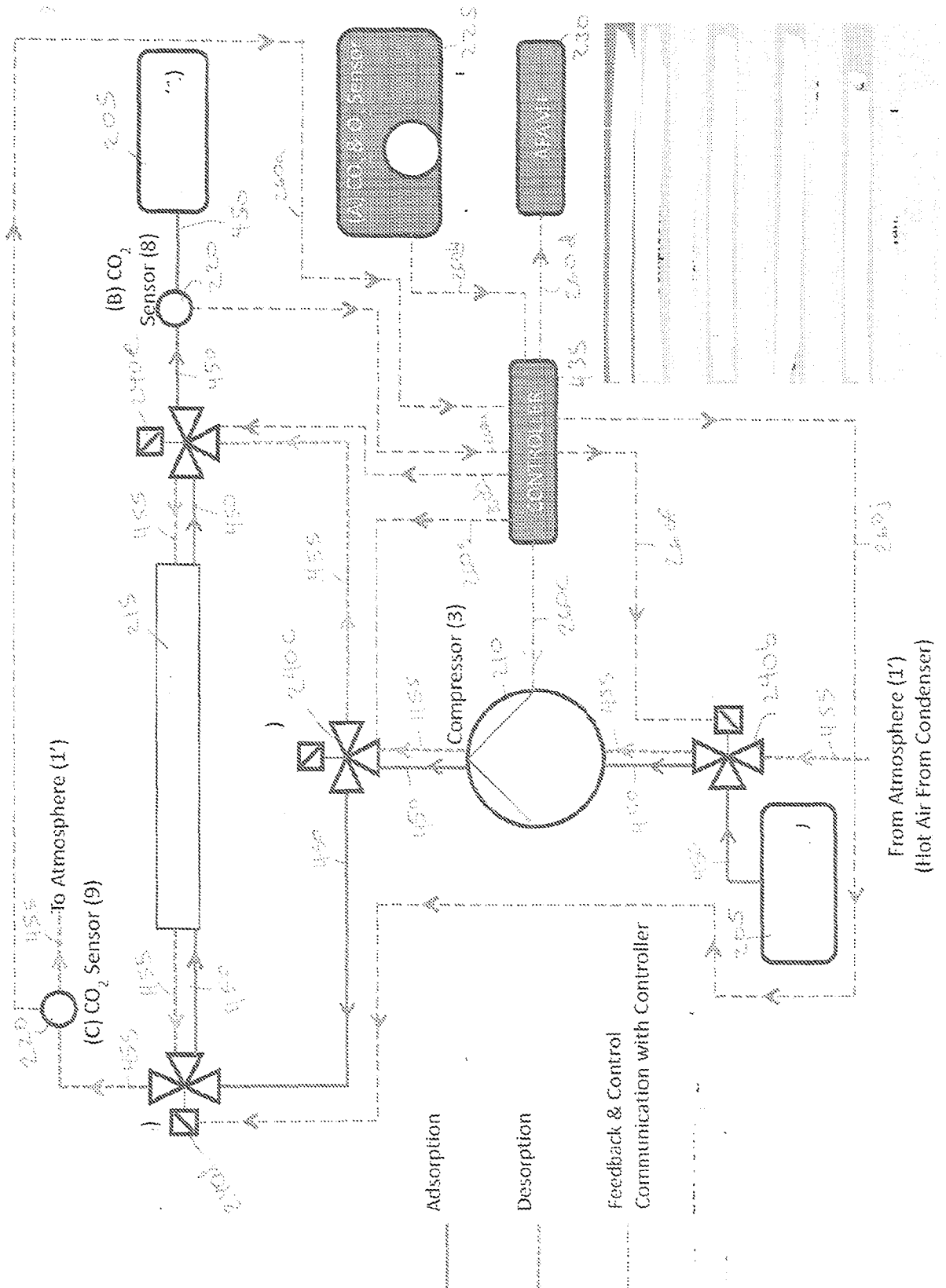
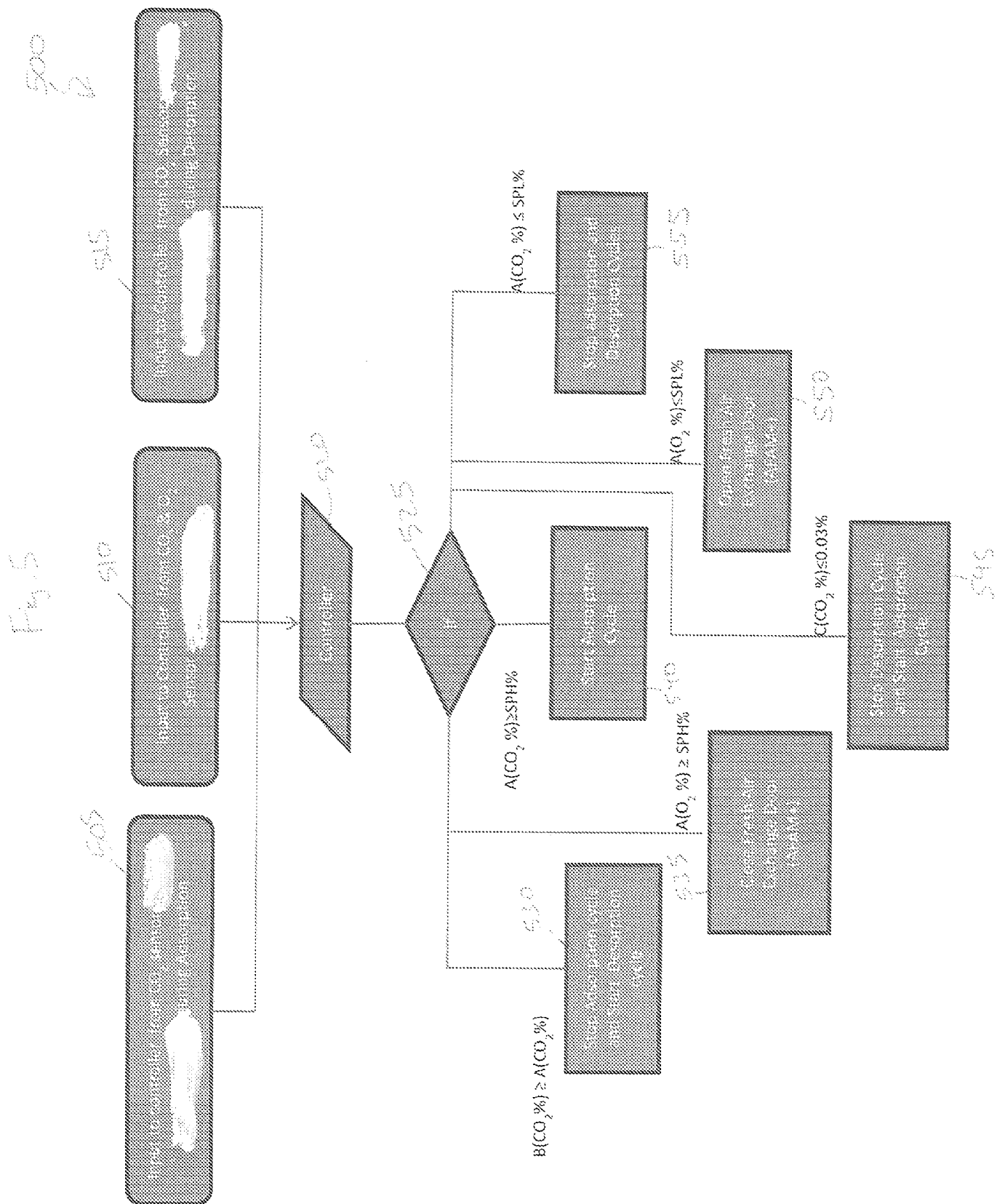


Fig. 3

Fig 4  
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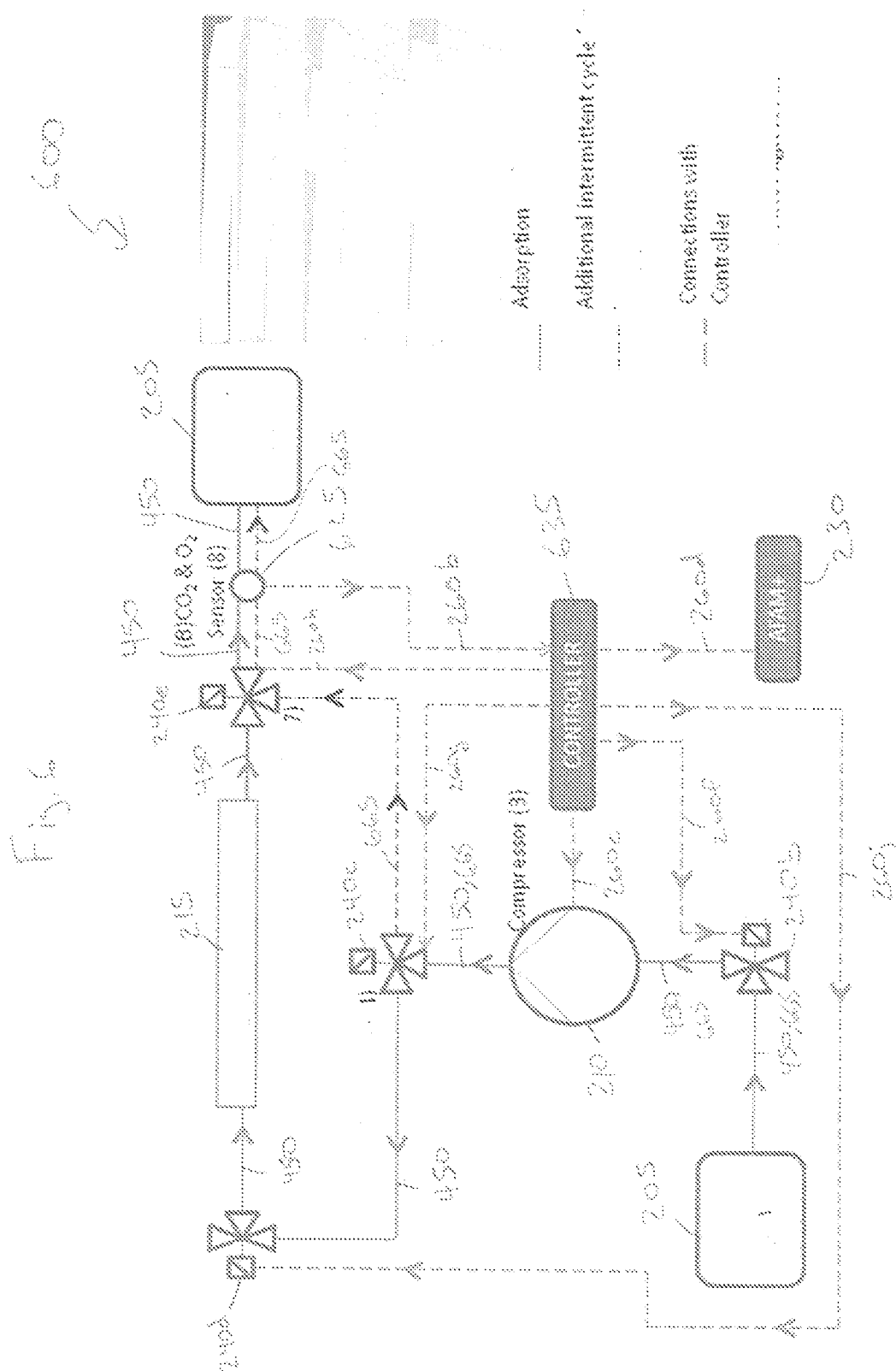
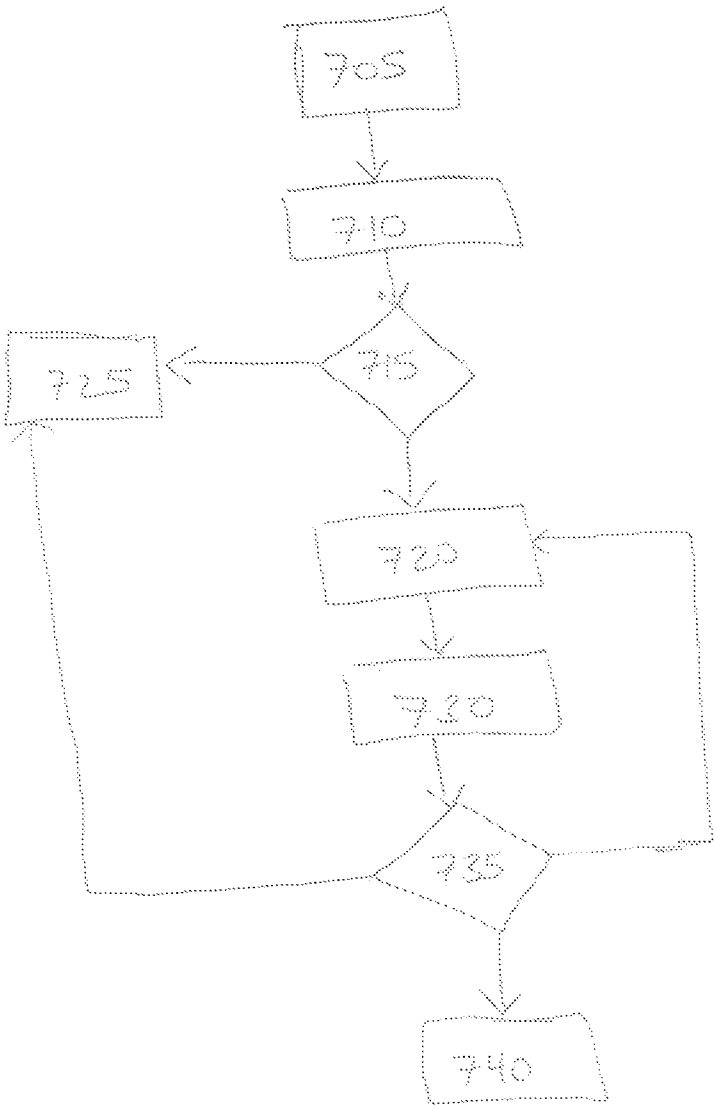
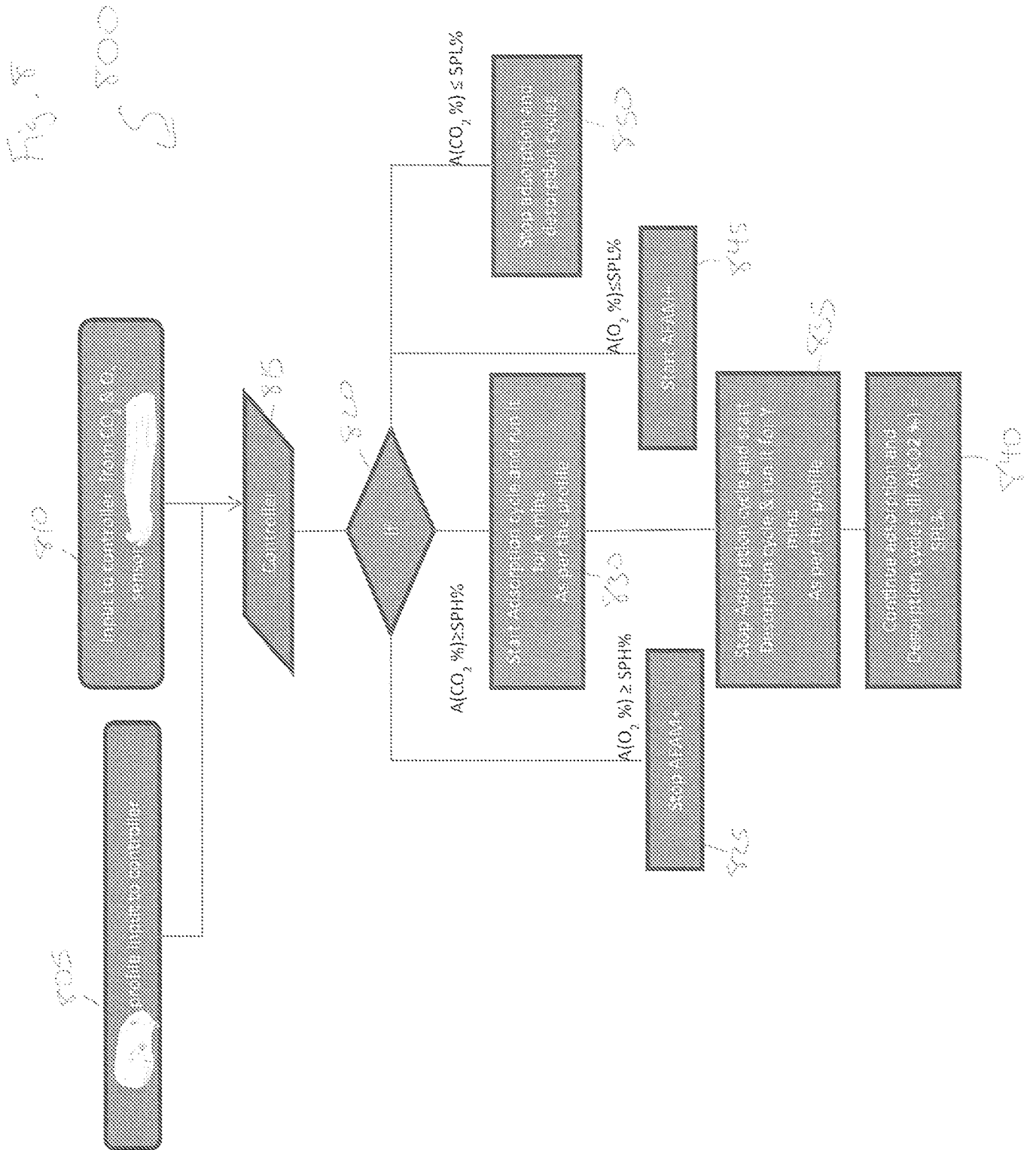


Fig 7

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## INTERNATIONAL SEARCH REPORT

International application No.  
**PCT/US2015/035394****A. CLASSIFICATION OF SUBJECT MATTER****F25B 49/00(2006.01)i, F25B 43/00(2006.01)i, B60P 3/20(2006.01)i**

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)

F25B 49/00; G01N 33/00; F24F 3/16; B01D 53/14; A23B 7/148; B01D 53/04; B01D 53/047; F25B 43/00; B60P 3/20

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) &amp; Keywords: storage, container, oxygen, carbon dioxide, scrubber, regeneration, desorption, adsorption, and perishable

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                                                                             | Relevant to claim No. |
|-----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| Y         | EP 0457431 B1 (TRANSFRESH CORPORATION) 01 October 1997<br>See column 3, line 52 - column 4, line 4, column 7, lines 28-30, column 31, lines 2-33 and figure 1. | 1-16                  |
| Y         | US 2012-0325086 A1 (SCHAEFER, JAMES C.) 27 December 2012<br>See paragraphs [0004], [0021]-[0024], [0040] and figure 1.                                         | 1-16                  |
| A         | US 2014-0202183 A1 (CHADWICK et al.) 24 July 2014<br>See paragraphs [0040]-[0043] and figure 1.                                                                | 1-16                  |
| A         | US 6113671 A (GARRETT, MICHAEL E.) 05 September 2000<br>See column 2, line 66 - column 4, line 27 and figure 1.                                                | 1-16                  |
| A         | US 6460352 B1 (LEMCOFF et al.) 08 October 2002<br>See column 5, line 36 - column 6, line 63 and figure 1.                                                      | 1-16                  |



Further documents are listed in the continuation of Box C.



See patent family annex.

\* Special categories of cited documents:

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"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

"&amp;" document member of the same patent family

Date of the actual completion of the international search

18 September 2015 (18.09.2015)

Date of mailing of the international search report

**21 September 2015 (21.09.2015)**

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**INTERNATIONAL SEARCH REPORT**

Information on patent family members

International application No.

**PCT/US2015/035394**

| Patent document<br>cited in search report | Publication<br>date | Patent family<br>member(s)                                                                                                                                                                            | Publication<br>date                                                                                                                                                  |
|-------------------------------------------|---------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| EP 0457431 B1                             | 01/10/1997          | AU 653513 B2<br>AU 7430191 A<br>DE 69127769 D1<br>DE 69127769 T2<br>DK 0457431 T3<br>EP 0457431 A2<br>EP 0457431 A3<br>ES 2110429 T3<br>NZ 237801 A<br>US 5872721 A<br>WO 91-15719 A1<br>ZA 9102658 A | 06/10/1994<br>17/10/1991<br>06/11/1997<br>14/05/1998<br>18/05/1998<br>21/11/1991<br>02/09/1992<br>16/02/1998<br>28/03/1995<br>16/02/1999<br>17/10/1991<br>27/01/1993 |
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