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(54) Title: CARBON DIOXIDE INJECTION IN A TRANSPORT UNIT

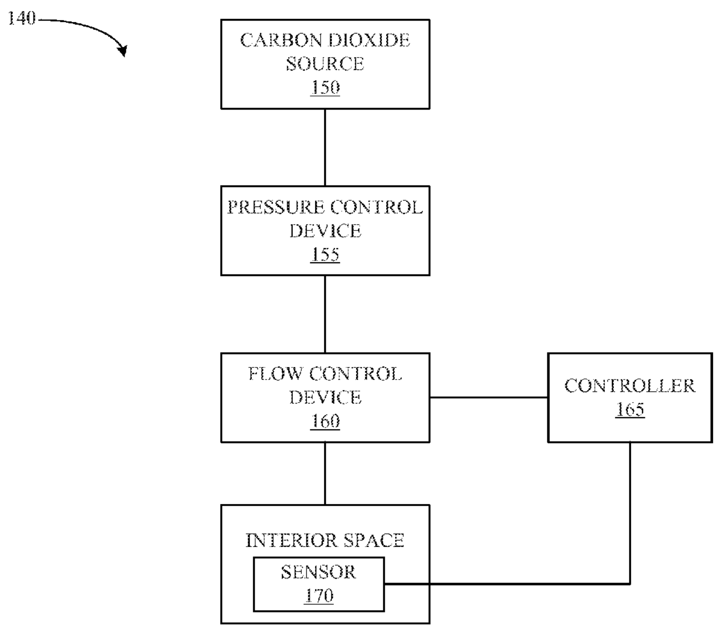

FIG. 2

(57) Abstract: A system and method for maintaining a desired carbon dioxide concentration within an interior space of a transport unit during transport are disclosed, The method includes determining the carbon dioxide concentration within the interior space; enabling a carbon dioxide injection system when the carbon dioxide concentration is not at a set point value; and disabling the carbon dioxide injection system when the carbon dioxide concentration is at the set point value.

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CARBON DIOXIDE INJECTION IN A TRANSPORT UNIT

FIELD

This disclosure relates generally to a controlled atmosphere system (CAS) and a method for controlling the CAS. More specifically, the disclosure relates to a method for controlling an atmospheric gas in a transport refrigeration system (TRS).

BACKGROUND

A controlled atmosphere system (CAS) is generally used to control an atmospheric parameter such as, but not limited to, a nitrogen content, an oxygen content, and/or a carbon dioxide content within a storage space such as, but not limited to, a transport unit. Examples of a transport unit include, but are not limited to, a container on a flat car, an intermodal container, a truck, a boxcar, or other similar transport unit. A transport unit is commonly used to transport perishable cargo such as, but not limited to, produce, frozen foods, and/or meat products. By controlling one or more atmospheric parameters within the transport unit, the rate of, for example, ripening of perishable cargo stored in the transport unit can be reduced.

SUMMARY

This disclosure relates generally to a controlled atmosphere system (CAS) and a method for controlling the CAS. More specifically, the disclosure relates to a method for controlling an atmospheric gas in a transport refrigeration system (TRS).

A system and method for maintaining a desired carbon dioxide concentration within an interior space of a transport unit during transport are disclosed. In some embodiments, the system and method can be used while the transport unit is in transport. In some embodiments, the system and method can be used while the transport unit is stationary (e.g., at a storage facility, etc.).

In some embodiments, a carbon dioxide injection system can be used to control a carbon dioxide concentration within a transport unit. In some embodiments, the carbon dioxide injection system can be used to increase the carbon dioxide concentration within the transport unit. In some embodiments, the carbon dioxide injection system can include a conventional CAS which can be used to decrease the carbon dioxide and/or oxygen concentration within the transport unit. In some embodiments, the carbon dioxide injection system can be used to identify a carbon

dioxide leak rate of an interior space of a transport unit. In some embodiments, identifying a carbon dioxide leak rate of the interior space of the transport unit can provide an indication as to whether a CAS will function properly. In some embodiments, identifying a carbon dioxide leak rate of the interior space of the transport unit can be used to determine whether an injected amount of carbon dioxide will be unreasonably high (e.g., too high of a concentration of the carbon dioxide in the interior space of the transport unit).

A method for controlling a carbon dioxide concentration within an interior space of a transport unit is disclosed. The method includes determining the carbon dioxide concentration within the interior space; enabling a carbon dioxide injection system when the carbon dioxide concentration is not at a set point value; and disabling the carbon dioxide injection system when the carbon dioxide concentration is at the set point value.

A carbon dioxide injection system for controlling a carbon dioxide concentration within an interior space of a transport unit during transport is disclosed. The system includes a carbon dioxide source; a pressure control device; and a flow control device, the carbon dioxide source, the pressure control device, and the flow control device being fluidly connected and in fluid communication with the interior space of the transport unit. The system further includes a controller configured to selectively enable and/or disable flow from the carbon dioxide source to the interior space of the transport unit.

A transport unit is disclosed. The transport unit includes a transport refrigeration unit; and a carbon dioxide injection system for controlling a carbon dioxide concentration within an interior space of the transport unit during transport. The carbon dioxide injection system includes a carbon dioxide source; a pressure control device; and a flow control device. The carbon dioxide source, the pressure control device, and the flow control device are fluidly connected and in fluid communication with the interior space of the transport unit. The carbon dioxide injection system also includes a controller configured to selectively enable and/or disable flow from the carbon dioxide source to the interior space of the transport unit.

BRIEF DESCRIPTION OF THE DRAWINGS

References are made to the accompanying drawings that form a part of this disclosure, and which illustrate the embodiments in which the systems and methods described in this specification can be practiced.

Fig. 1 illustrates a transport unit with which the embodiments described in this specification can be practiced, according to some embodiments.

Fig. 2 illustrates a block diagram of a carbon dioxide injection system for use in a transport unit, according to some embodiments.

Fig. 3 illustrates a block diagram of a controlled atmosphere system (CAS) for use as a carbon dioxide source in a carbon dioxide injection system, according to some embodiments.

Fig. 4 illustrates a flowchart for a method to control a carbon dioxide concentration within a transport unit, according to some embodiments.

Like reference numbers represent like parts throughout.

DETAILED DESCRIPTION

This disclosure relates generally to a controlled atmosphere system (CAS) and a method for controlling the CAS. More specifically, the disclosure relates to a method for controlling an atmospheric gas in a transport refrigeration system (TRS).

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

A “controlled atmosphere system” (CAS) includes, for example, a controlled atmosphere circuit for controlling one or more atmospheric parameters within an interior space of a transport unit. Examples of atmospheric parameters within the interior space include, but are not limited to, a content of nitrogen, a content of oxygen, and/or a content of carbon dioxide in the air contained within the interior space.

A “transport refrigeration system” (TRS) includes, for example, a refrigeration circuit for controlling the refrigeration of an interior space of a transport unit. The TRS may be a vaporcompression type refrigeration system, or any other suitable refrigeration system that can use refrigerant, cold plate technology, or the like.

A "transport unit" includes, for example, a container (e.g., a container on a flat car, an intermodal container, etc.), a truck, a boxcar, or other similar transport unit.

A "CAS controller" includes, for example, an electronic device (e.g., a processor, memory, etc.) that is configured to manage, command, direct, and regulate the behavior of one or more components of a CAS (e.g., an air compressor, one or more flow valves, one or more sensors, one or more switches, etc.). In some embodiments, the CAS controller can be part of a controller configured to manage, command, direct, and regulate the behavior of one or more components of a refrigeration circuit (e.g., an evaporator, a condenser, a compressor, an expansion valve (EXV), an electronic throttling valve (ETV), etc.), one or more components of an power unit powering, for example, the CAS and a refrigeration circuit, etc.

Fig. 1 illustrates a transport unit 100 with which the embodiments described in this specification can be practiced, according to some embodiments. The transport unit 100 includes a transport refrigeration unit (TRU) 10 and a carbon dioxide injection system 140. It is to be appreciated that the transport unit 100 can include one or more additional components. It is further to be appreciated that the carbon dioxide injection system 140 can be incorporated within the TRU 10, according to some embodiments. In other embodiments, the carbon dioxide injection system 140 can be incorporated within an interior space of the transport unit 100.

The TRU 10 can generally be used to control one or more environmental conditions within the interior space of the transport unit 100. Examples of the one or more environmental conditions include, but are not limited to, temperature, air quality, humidity, or the like. The TRU 10 generally operates according to principles known in the art.

It is to be appreciated that the transport unit 100 can be a variety of other types of transport units other than a container as illustrated. Examples of alternative transport units include, but are not limited to, a trailer, a boxcar, a truck with a cargo space, or other similar storage compartment designed for transporting cargo. The type of the transport unit 100 is not intended to be limiting, though it is to be appreciated that the systems and methods described in this specification may have varying levels of efficacy depending upon the type of the transport unit 100.

The carbon dioxide injection system 140 can be configured to control one or more atmospheric parameters (e.g., an oxygen content, a carbon dioxide content, a nitrogen content, content of other gases (e.g., ethylene, ozone, etc.), or the like) within the interior space of the transport unit 100. In particular, the carbon dioxide injection system 140 can be configured to add carbon dioxide to the atmosphere of the interior space in the transport unit 100. In some embodiments, the carbon dioxide injection system 140 can also be configured to separate nitrogen from, for example, ambient air and supply nitrogen to the interior space of the transport unit 100. In some embodiments, the carbon dioxide injection system 140 is configured for controlling the carbon dioxide concentration within the interior space of the transport unit 100 while the transport unit 100 is in transit. In some embodiments, the carbon dioxide injection system 140 is configured for controlling the carbon dioxide concentration within the interior space of the transport unit 100 while the transport unit 100 is not in transit (e.g., while at a storage facility, etc.).

The TRU 10 and the carbon dioxide injection system 140 can be configured to work together in order to provide a desired atmospheric condition for the interior space that is suitable, for example, for transporting perishable goods such as, but not limited to, fruits and vegetables.

Fig. 2 illustrates a block diagram of the carbon dioxide injection system 140 (Fig. 1), according to some embodiments. The carbon dioxide injection system 140 generally includes a carbon dioxide source 150, a pressure control device 155, a flow control device 160, a controller 165, and a sensor 170 (e.g., a carbon dioxide concentration sensor or the like that is disposed within an interior space 105 of the transport unit 100).

The carbon dioxide source 150 can be any means for supplying carbon dioxide gas to the interior space of the transport unit 100. In some embodiments, the carbon dioxide source 150 can be a pressurized cylinder including carbon dioxide. In some embodiments, the pressurized cylinder can have a volume between about 10 and about 100 liters. In some embodiments, the pressurized cylinder including carbon dioxide can be stored at about 50 bar. In some embodiments the carbon dioxide 150 can be placed inside the interior space of the transport unit 100. In other embodiments, the carbon dioxide source 150 can be placed outside the interior space of the transport unit 100. In some embodiments, the carbon dioxide source 150 can be a high pressure storage container having a volume between about 30 and about 200 liters. In some embodiments, the high-pressure storage container can store the carbon dioxide at about 50 bar and can be placed either in the interior space or outside the interior space of the transport unit 100. In some embodiments, the carbon dioxide source 150 includes a controlled atmosphere system (CAS) such as CAS 200 shown and described in accordance with Fig. 3 below. It is to be appreciated that the carbon dioxide source 150 is not intended to be limited to the above-described embodiments and that other carbon dioxide sources may be implemented within the scope of this disclosure. It is to be appreciated that this volume range is intended to be exemplary and that the volume of the carbon dioxide source 150 can vary depending upon the embodiment. Further, the pressures are intended to be exemplary and can vary according to the principles described herein.

The pressure control device 155 is generally configured to reduce a pressure of the carbon dioxide coming from the carbon dioxide source 155. As described above, the carbon dioxide source 150 can include carbon dioxide stored under pressure. The pressure control device 155 can reduce the pressure of the carbon dioxide. In some embodiments, the carbon dioxide can be reduced from a pressure of about 50 bar to a pressure of about 2 bar. In some embodiments, the pressure can be reduced to about atmospheric pressure. The pressure reduction can, for example, be based on a safety requirement. In some embodiments, the pressure reduction can be selected such that the pressure control device 155 does not freeze due to the reduction in pressure. The pressure control device 155 generally functions according to principles known in the art.

The flow control device 160 can generally be configured to allow flow of the carbon dioxide to the interior space of the transport unit 100 or the prevent flow of the carbon dioxide to the interior space of the transport unit 100. In some embodiments, the flow control device 160 can be a solenoid valve having a flow enabled position and a flow disabled position. In some embodiments, the flow control device 160 can include a valve having a flow-enabled position, a flow disabled position, and one or more intermediate positions in which a partial flow of carbon dioxide is enabled. The flow control device 160 generally operates according to principles known in the art. The controller 165 can control the state (e.g., flow enabled, flow disabled, etc.) of the flow control device 160. A method for controlling the state of the flow control device 160 is discussed in additional detail in accordance with Fig. 4 below.

The controller 165 can be, for example, an electronic device that is configured to manage, command, direct, and regulate the behavior of one or more components (e.g., the flow control device 160, etc.) of the carbon dioxide injection system 140. The controller 165 controls the carbon dioxide injection system 140 to obtain an environmental condition (e.g., a concentration of carbon dioxide) in the interior space of the transport unit 100. The controller 165 can be in communication with the flow control device 160 and the sensor 170. The controller 165 can be powered by, for example, a battery (not shown).

The sensor 170 is disposed within the interior space of the transport unit 100. In some embodiments, the sensor 170 can be a carbon dioxide sensor configured to determine a concentration of carbon dioxide within the atmosphere of the interior space of the transport unit 100. The sensor 170 is configured to determine the concentration of carbon dioxide in the interior space of the transport unit 100 and provide the determined carbon dioxide concentration to the controller 165. The controller 165 can use the determined carbon dioxide concentration to control the flow control device 160 (e.g., flow enabled, flow disabled, etc., as discussed in additional detail in accordance with Fig. 4 below).

Fig. 3 illustrates a controlled atmosphere system (CAS) 200 for a carbon dioxide source (e.g., carbon dioxide source 150 of the carbon dioxide injection system 140 in Fig. 2) for a transport unit 202, such as the transport unit 100 shown in Fig. 1.

The basic components of the CAS 200 include an air compressor 205, a particulate filter 210, a heat exchanger 215, a nitrogen separation membrane 220, a system of metering valves 225, a plurality of gas sensors 230, and a CAS controller 235.

The CAS 200 is configured to control the amount of oxygen and carbon dioxide inside the transport unit 202 to change the rate of ripening of cargo (not shown) stored in the transport unit 202. The CAS 200 can control the amount of oxygen (O_2) and carbon dioxide (CO_2) by introducing nitrogen (N_2) generated from the nitrogen separation membrane 220.

When the CAS 200 is running, ambient air 201 from outside the transport unit 202 enters the air compressor 205 through a dust filter 240. In some embodiments, air from inside the transport unit 202 can also be directed to the air compressor 205 through the dust filter 240 via an intake line 275. The atmospheric air is then compressed to a high pressure by the air compressor 205. High pressure air from the particulate filter 210 passes to the heat exchanger 215 where it can be temperature conditioned (e.g., heated or cooled) to an optimum operating temperature. The CAS controller 235 receives temperature data from a heat exchanger temperature sensor 217 and can control operation of a heat exchanger switch 219 to maintain the temperature of compressed air leaving the heat exchanger 215. The high-pressure, temperature conditioned air is then filtered by the particulate filter 210 to remove moisture, dirt, and/or other air contaminants (e.g., oil, ozone, hydrocarbons, etc.) before passing to the membrane 220. In some embodiments, the particulate filter 210 can include a plurality of particulate filters 210. A normally opened drain valve 245 is provided on the particulate filter 210. It will be appreciated that the drain valve 245 can alternatively be a normally closed drain valve. A normally opened drain valve 245 can, for example, allow fluid to drain out in case of a power loss, which can prevent freezing of the particulate filter 210 and/or the drain valve 245. In some embodiments, the drain valve 245 can be an automated drain valve in which the drain valve 245 is adapted to be opened and/or closed when instructed by the CAS controller 235. The CAS controller 235 can be programmed to periodically open the drain valve 245, for a short time, to remove residue which may build up in the particulate filter 210. In some embodiments, the drain valve 245 may not be included if the particulate filter 210 includes an automatic drain.

The temperature conditioned, high pressure air passing from the heat exchanger 215 enters the nitrogen separation membrane 220, where it can be separated into high purity nitrogen, which passes from a nitrogen outlet 212, and oxygen/and other gases which are passed to an oxygen outlet 214. The rate of separation occurring in the nitrogen separation membrane 220 depends on the flow of air through the nitrogen separation membrane 220. This flow rate is controlled by the pressure in the nitrogen outlet 212. The higher the pressure in the nitrogen outlet 212, the higher the nitrogen purity generated, and the lower the flow rate of nitrogen. The nitrogen separation membrane 220 can be capable of generating nitrogen purity levels greater than, for example, about 99 percent. As the pressure in the nitrogen outlet 212 falls, the purity level of the nitrogen falls, and the flow rate increases.

The nitrogen enriched gas passing from the nitrogen separation membrane 220 through the nitrogen outlet 212 passes to the flow control valves 225. The oxygen/other gasses from the oxygen outlet 214 are exhausted to the outside air.

The pressure on the nitrogen outlet 212 of the nitrogen separation membrane 220 is regulated by the aforementioned flow control valves 225. To control the percentage of nitrogen present in the transport unit 202, the CAS controller 235 can be programmed to cycle the flow control valves 225 to increase or decrease the amount/purity of nitrogen in the transport unit 202 as required. The CAS controller 235 may also add carbon dioxide from an external carbon dioxide source 250 if desired.

In some embodiments (e.g., during a ventilation mode), the temperature conditioned, high pressure air passing from the heat exchanger 215 can bypass the nitrogen separation membrane 220 and pass directly to the transport unit 202 via a bypass line 270. Accordingly, the amount of oxygen in the transport unit 202 can be increased and the amount of carbon dioxide in the transport unit 202 can be decreased.

The gas sensors 230 can include, for example, an oxygen concentration sensor, a carbon dioxide concentration sensor, an ethylene concentration sensor, etc. Periodic calibration of the gas sensors 230 to correct drifts with time and temperature can require sampling outside air via a line 260. The gas sensors 230 can be provided at various locations within the transport unit 202.

The CAS controller 235 is configured to monitor the amount of oxygen and carbon dioxide in the transport unit 202, using the gas sensors 230 via a sample line 255. The oxygen and carbon dioxide concentrations monitored by the CAS controller 235 can be stored in a data recorder 280.

Fig. 4 illustrates a flowchart for a method 400 to control a carbon dioxide concentration within a transport unit (e.g., the transport unit 100 of Fig. 1), according to some embodiments.

The method 400 generally is directed to determining a concentration of carbon dioxide in an atmosphere of an interior space of the transport unit 100 and adding carbon dioxide (e.g., increasing a concentration of carbon dioxide) or ventilating the interior space (e.g., reducing a concentration of carbon dioxide) for the transport unit 100.

The method 400 begins at 405 when a controller (e.g., the controller 165 of Fig. 2) determines a concentration of carbon dioxide in the interior space of the transport unit 100. The controller 165 can determine the concentration of carbon dioxide in the interior space of the transport unit 100 through a sensor (e.g., the sensor 170 of Fig. 2).

At 410 the controller determines whether the carbon dioxide concentration is about the same as a carbon dioxide concentration set point value. The carbon dioxide set point value can vary depending upon a variety of factors. For example, the carbon dioxide set point can vary based on a cargo being transported within the interior space of the transport unit 100, a duration of a trip, a user preference, or the like.

If the carbon dioxide concentration is not at about the set point value in 410, a carbon dioxide injection system (e.g., the carbon dioxide injection system 140 of Figs. 1 – 2) is enabled at 415. Enabling the carbon dioxide injection system 140 can include enabling flow from a carbon dioxide source (e.g., the carbon dioxide source 150 of Fig. 2) by modifying a flow control device (e.g., the flow control device 160 of Fig. 2) such that flow of the carbon dioxide is enabled from the carbon dioxide source 150 to the interior space of the transport unit 100. Once the carbon dioxide injection system 140 is enabled at 415, the method 400 returns to 405 and the controller determines the concentration of carbon dioxide in the interior space of the transport unit 100.

If the carbon dioxide concentration is about the same as the set point value, the carbon dioxide injection system 140 is disabled at 420. In some embodiments, disabling the carbon dioxide injection system 140 can, for example, include modifying the flow control device 160 such that flow of carbon dioxide from the carbon dioxide source 150 to the interior space of the transport unit 100 is prevented.

At 425 the carbon dioxide concentration in the interior space of the transport unit 100 is determined again by the controller 165. At 430, the controller determines whether the carbon dioxide concentration is within a threshold range of the set point value. For example, the threshold range can be an acceptable deviation from the set point value (both above the set point value and below the set point value). In some embodiments, the controller 165 determines the carbon dioxide concentration from the sensor 170 disposed within the interior space of the transport unit 100.

If the carbon dioxide concentration is within the threshold range, the method 400 continues to 425 and monitors the concentration of the carbon dioxide within the interior space of the transport unit 100 until the carbon dioxide concentration is outside the threshold range.

If the carbon dioxide concentration is not within the threshold range, the controller determines whether the carbon dioxide concentration is above the threshold range at 435. If the carbon dioxide concentration is above the threshold range at 435, the controller 165 will ventilate the interior space of the transport unit 100 at 440. In some embodiments, ventilating the interior space of the transport unit 100 can be accomplished by enabling a CAS (e.g., the CAS 200 of Fig. 3). The method 400 then continues to 430 to monitor whether the carbon dioxide concentration returns to within the threshold range of the set point value.

If the carbon dioxide concentration is not within the threshold range and the carbon dioxide concentration is not above the threshold range at 435 (e.g., the carbon dioxide concentration in the interior space of the transport unit 100 is below the lower bound of the threshold range of the set point value), the method continues to 415 and enables the carbon dioxide injection system 140.

Aspects:

It is to be appreciated that aspects 1 – 6 can be combined with any one of aspects 7 – 11 or 12 – 15. Further, any one of aspects 7 – 11 can be combined with any one of aspects 12 – 15.

Aspect 1. A method for controlling a carbon dioxide concentration within an interior space of a transport unit, the method comprising:

determining the carbon dioxide concentration within the interior space;

enabling a carbon dioxide injection system when the carbon dioxide concentration is not at a set point value; and

disabling the carbon dioxide injection system when the carbon dioxide concentration is at the set point value.

Aspect 2. The method according to aspect 1, wherein determining the carbon dioxide concentration includes determining a sensor reading from a sensor disposed within the interior space of the transport unit.

Aspect 3. The method according to any one of aspects 1 – 2, wherein enabling the carbon dioxide injection system includes positioning a flow control device such that flow from a carbon dioxide source to the interior space of the transport unit is enabled.

Aspect 4. The method according to aspect 3, wherein disabling the carbon dioxide injection system includes positioning the flow control device such that flow from the carbon dioxide source to the interior space of the transport unit is disabled.

Aspect 5. The method according to any one of aspects 1 – 4, further comprising:

enabling the carbon dioxide injection system when the carbon dioxide concentration is lower than a threshold range based on the set point value.

Aspect 6. The method according to any one of aspects 1 – 5, further comprising:

ventilating the interior space to decrease the carbon dioxide concentration when the carbon dioxide concentration is greater than a threshold range based on the set point value.

Aspect 7. A carbon dioxide injection system for controlling a carbon dioxide concentration within an interior space of a transport unit during transport, the system comprising:

a carbon dioxide source;

a pressure control device;

a flow control device, wherein the carbon dioxide source, the pressure control device, and the flow control device are fluidly connected and in fluid communication with the interior space of the transport unit; and

a controller configured to selectively enable and/or disable flow from the carbon dioxide source to the interior space of the transport unit.

Aspect 8. The system according to aspect 7, further comprising a carbon dioxide sensor, wherein the carbon dioxide sensor is configured to be in electronic communication with the controller.

Aspect 9. The system according to any one of aspects 7 – 8, wherein the controller is configured to selectively enable the flow from the carbon dioxide source to the interior space of the transport unit in response to a concentration of carbon dioxide within the interior space falling below a threshold.

Aspect 10. The system according to any one of aspects 7 – 9, wherein the controller is configured to selectively disable the flow from the carbon dioxide source to the interior space of the transport unit in response to a concentration of carbon dioxide within the interior space being above a threshold.

Aspect 11. The system according to any one of aspects 7 – 10, wherein the carbon dioxide source is one of a pressurized cylinder, a high pressure storage container, or a controlled atmosphere system.

Aspect 12. A transport unit, comprising:

a transport refrigeration unit; and

a carbon dioxide injection system, the carbon dioxide injection system for controlling a carbon dioxide concentration within an interior space of the transport unit during transport, the system including:

a carbon dioxide source;

a pressure control device;

a flow control device, wherein the carbon dioxide source, the pressure control device, and the flow control device are fluidly connected and in fluid communication with the interior space of the transport unit; and

a controller configured to selectively enable and/or disable flow from the carbon dioxide source to the interior space of the transport unit.

Aspect 13. The transport unit according to aspect 12, further comprising a controlled atmosphere system.

Aspect 14. The transport unit according to any one of aspects 12 – 13, wherein the interior space of the transport unit includes a sensor configured to determine a carbon dioxide concentration within the interior space.

Aspect 15. The transport unit according to any one of aspects 12 – 14, wherein the transport unit is one of a container on a flat car, an intermodal container, a truck, or a boxcar.

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 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 arrangement of parts without departing from the scope of the present disclosure. This specification and the embodiments described are exemplary only, with the true scope and spirit of the disclosure being indicated by the claims that follow.

CLAIMS

What is claimed is:

1. A method for controlling a carbon dioxide concentration within an interior space of a transport unit, the method comprising:

determining the carbon dioxide concentration within the interior space;

enabling a carbon dioxide injection system when the carbon dioxide concentration is not at a set point value; and

disabling the carbon dioxide injection system when the carbon dioxide concentration is at the set point value.

2. The method according to claim 1, wherein determining the carbon dioxide concentration includes determining a sensor reading from a sensor disposed within the interior space of the transport unit.

3. The method according to claim 1, wherein enabling the carbon dioxide injection system includes positioning a flow control device such that flow from a carbon dioxide source to the interior space of the transport unit is enabled.

4. The method according to claim 3, wherein disabling the carbon dioxide injection system includes positioning the flow control device such that flow from the carbon dioxide source to the interior space of the transport unit is disabled.

5. The method according to claim 1, further comprising:

enabling the carbon dioxide injection system when the carbon dioxide concentration is lower than a threshold range based on the set point value.

6. The method according to claim 1, further comprising:

ventilating the interior space to decrease the carbon dioxide concentration when the carbon dioxide concentration is greater than a threshold range based on the set point value.

7. A carbon dioxide injection system for controlling a carbon dioxide concentration within an interior space of a transport unit during transport, the system comprising:

a carbon dioxide source;

a pressure control device;

a flow control device, wherein the carbon dioxide source, the pressure control device, and the flow control device are fluidly connected and in fluid communication with the interior space of the transport unit; and

a controller configured to selectively enable and/or disable flow from the carbon dioxide source to the interior space of the transport unit.

8. The system according to claim 7, further comprising a carbon dioxide sensor, wherein the carbon dioxide sensor is configured to be in electronic communication with the controller.

9. The system according to claim 7, wherein the controller is configured to selectively enable the flow from the carbon dioxide source to the interior space of the transport unit in response to a concentration of carbon dioxide within the interior space falling below a threshold.

10. The system according to claim 7, wherein the controller is configured to selectively disable the flow from the carbon dioxide source to the interior space of the transport unit in response to a concentration of carbon dioxide within the interior space being above a threshold.

11. The system according to claim 7, wherein the carbon dioxide source is one of a pressurized cylinder, a high pressure storage container, or a controlled atmosphere system.

12. A transport unit, comprising:

a transport refrigeration unit; and

a carbon dioxide injection system, the carbon dioxide injection system for controlling a carbon dioxide concentration within an interior space of the transport unit during transport, the system including:

a carbon dioxide source;

a pressure control device;

a flow control device, wherein the carbon dioxide source, the pressure control device, and the flow control device are fluidly connected and in fluid communication with the interior space of the transport unit; and

a controller configured to selectively enable and/or disable flow from the carbon dioxide source to the interior space of the transport unit.

13. The transport unit according to claim 12, further comprising a controlled atmosphere system.

14. The transport unit according to claim 12, wherein the interior space of the transport unit includes a sensor configured to determine a carbon dioxide concentration within the interior space.

15. The transport unit according to claim 12, wherein the transport unit is one of a container on a flat car, an intermodal container, a truck, or a boxcar.

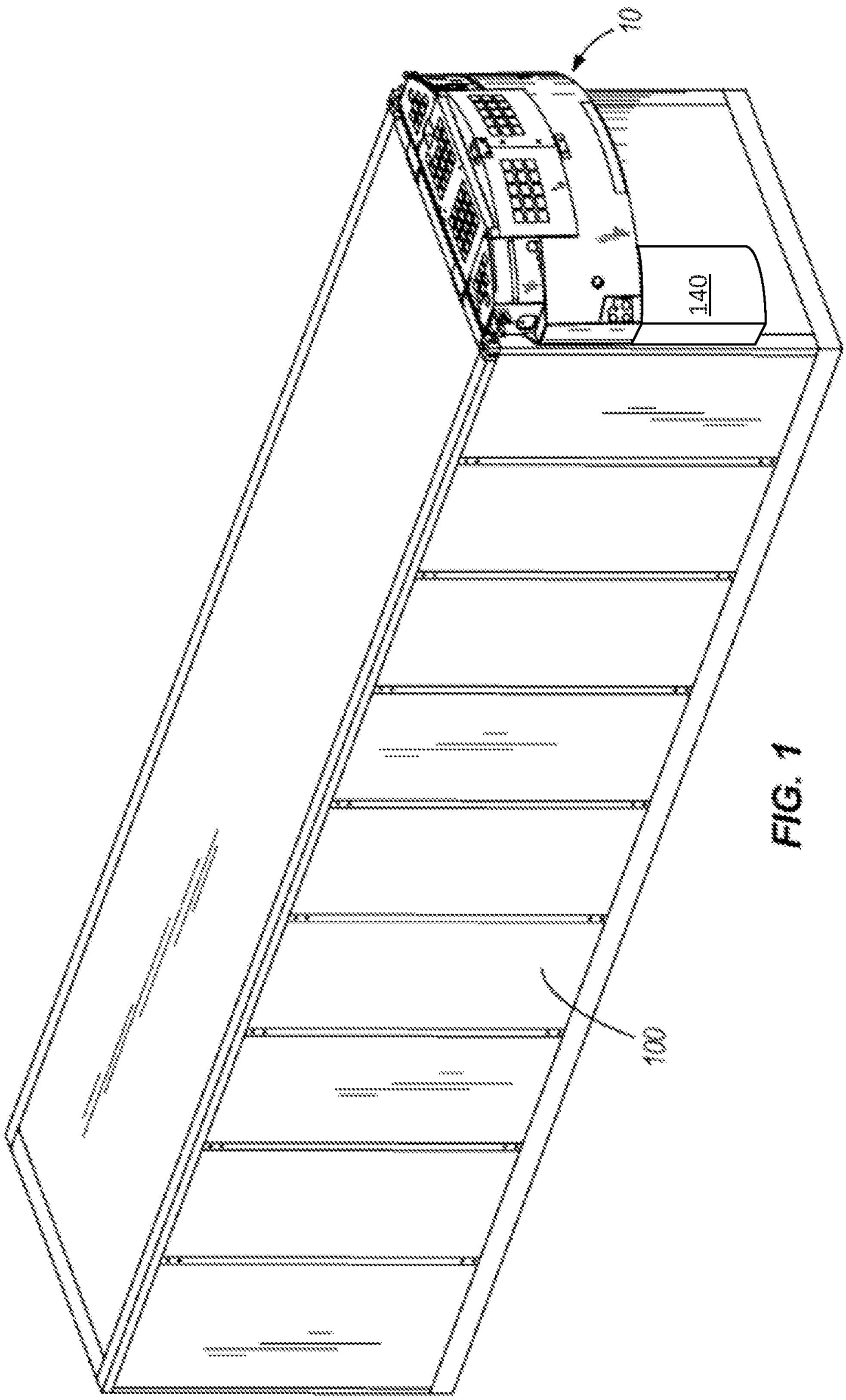

FIG. 1

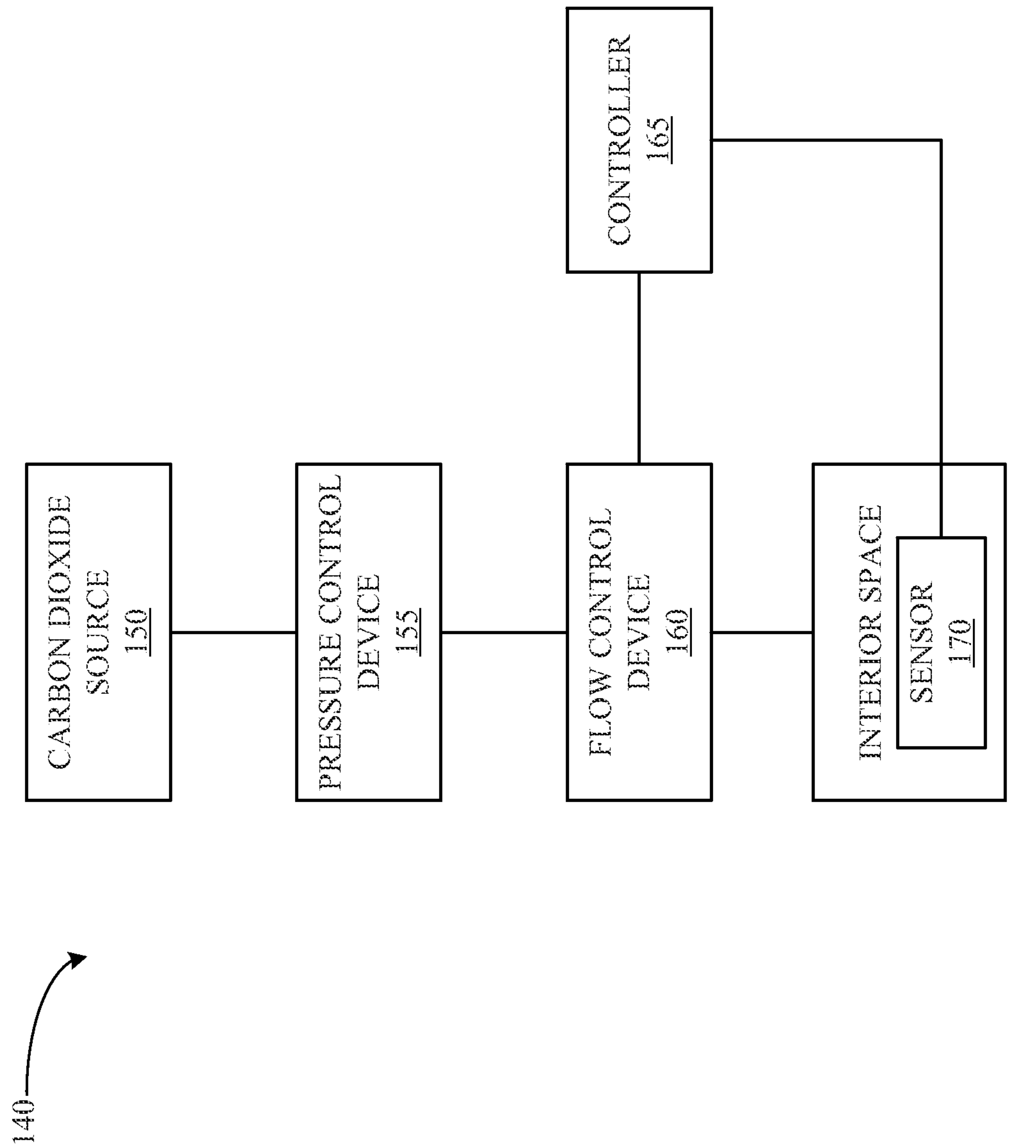
140
CARBON DIOXIDE SOURCE 150
PRESSURE CONTROL DEVICE 155
FLOW CONTROL DEVICE 160
CONTROLLER 165
INTERIOR SPACE
SENSOR 170

FIG. 2

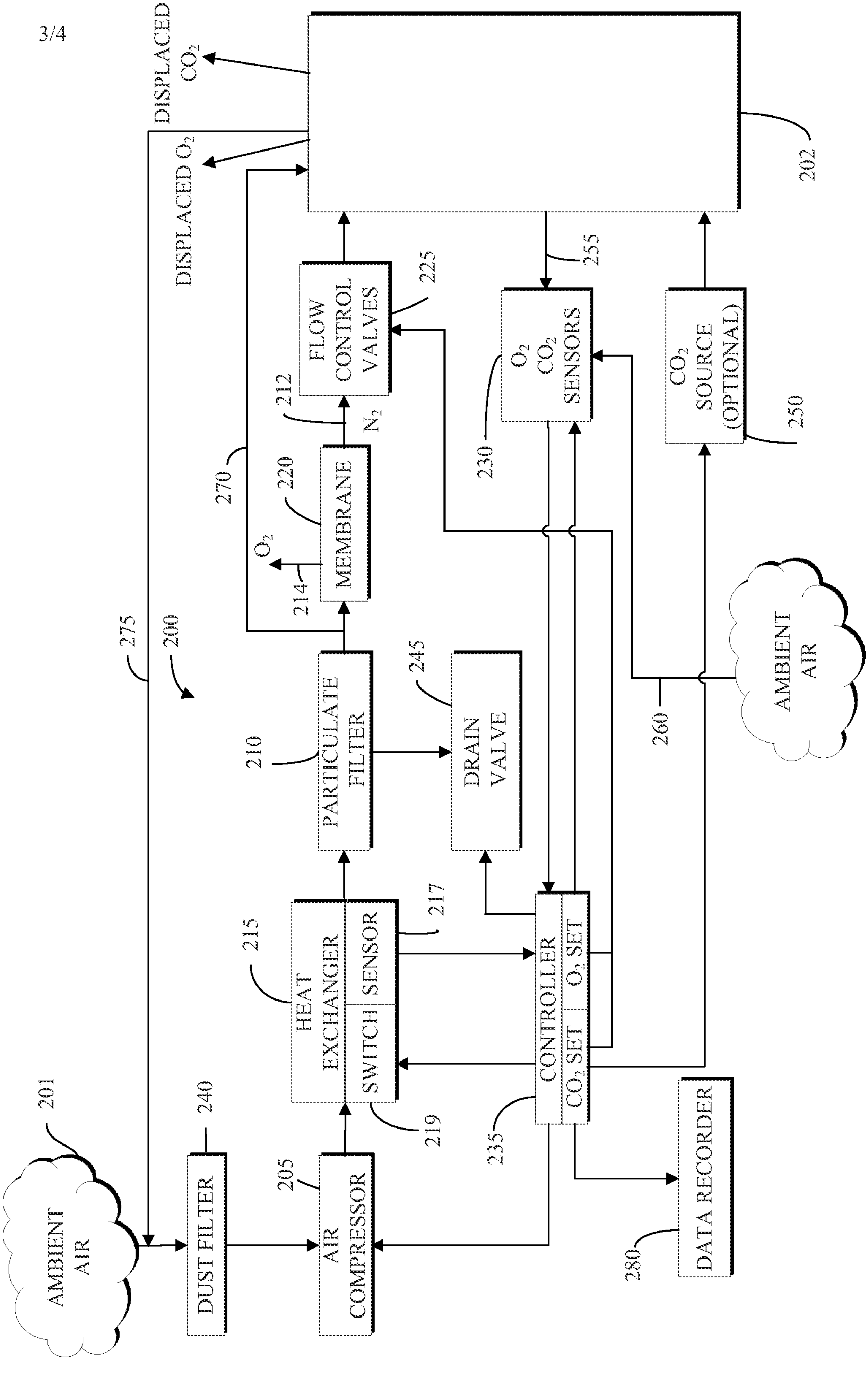
DISPLACED CO_2
DISPLACED O_2
202
200
275
270
AMBIENT AIR
201
DUST FILTER
240
AIR COMPRESSOR
205
HEAT EXCHANGER
215
SWITCH
219
SENSOR
217
PARTICULATE FILTER
210
DRAIN VALVE
245
MEMBRANE
220
O_2
214
N_2
212
FLOW CONTROL VALVES
225
O_2 CO_2 SENSORS
230
255
CO_2 SOURCE (OPTIONAL)
250
AMBIENT AIR
260
CONTROLLER
CO_2 SET
O_2 SET
235
DATA RECORDER
280

FIG. 3

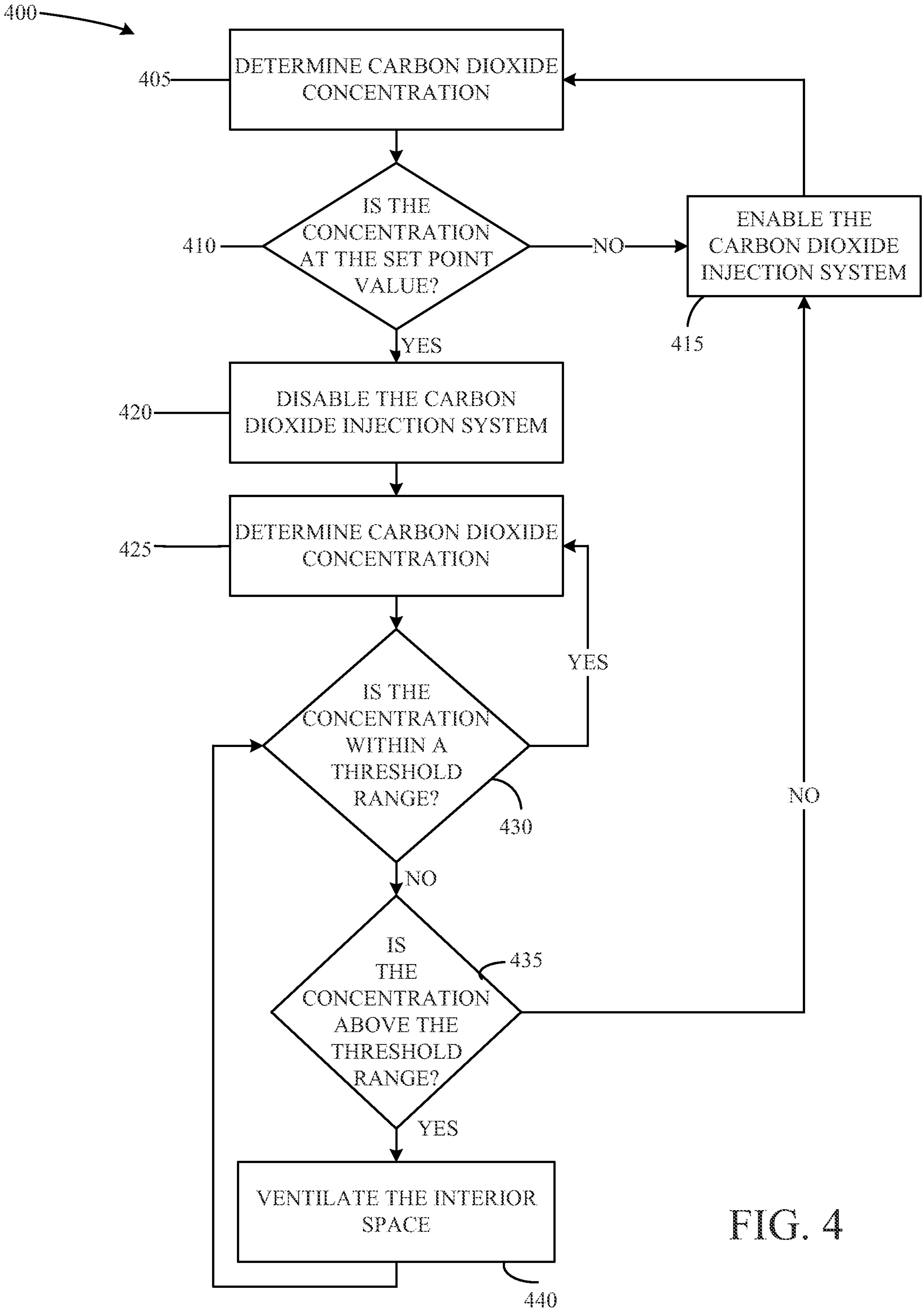
400
405
DETERMINE CARBON DIOXIDE CONCENTRATION
410
IS THE CONCENTRATION AT THE SET POINT VALUE?
NO
ENABLE THE CARBON DIOXIDE INJECTION SYSTEM
415
YES
420
DISABLE THE CARBON DIOXIDE INJECTION SYSTEM
425
DETERMINE CARBON DIOXIDE CONCENTRATION
YES
IS THE CONCENTRATION WITHIN A THRESHOLD RANGE?
430
NO
NO
IS THE CONCENTRATION ABOVE THE THRESHOLD RANGE?
435
YES
VENTILATE THE INTERIOR SPACE
440

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/035372

A. CLASSIFICATION OF SUBJECT MATTER

F25B 1/00(2006.01)i, F25B 29/00(2006.01)i, B60P 3/20(2006.01)i, B65D 88/74(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 1/00; B60H 1/32; F24F 3/16; B65B 31/04; F17C 7/02; F25B 29/00; B60P 3/20; B65D 88/74

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) & Keywords: transport unit, carbon dioxide, sensor, concentration, pressure

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5125237 A (SAIA, III et al.) 30 June 1992 See column 5, line 45 - column 9, line 20, claims 4-27, and figures 1-11.	1-15
A	US 7089751 B2 (FLEMING, JR. et al.) 15 August 2006 See column 2, line 60 - column 3, line 5 and figures 1, 2.	1-15
A	WO 96-12645 A1 (CORNELIUSSEN, CHRISTIAN) 02 May 1996 See page 6, line 29 - page 7, line 7 and figure 2.	1-15
A	US 4399658 A (NIELSEN, DEAN M.) 23 August 1983 See column 2, lines 27-58 and figures 1, 2.	1-15
A	US 5715685 A (TAKASUGI, MITSUO) 10 February 1998 See column 4, line 55 - column 7, line 14 and figures 1-5.	1-15

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
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"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
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
17 September 2015 (17.09.2015)	**18 September 2015 (18.09.2015)**

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2015/035372

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