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(54) **Title:** METHODS AND SYSTEMS FOR MONITORING A LEAK RATE OF A TRANSPORT UNIT

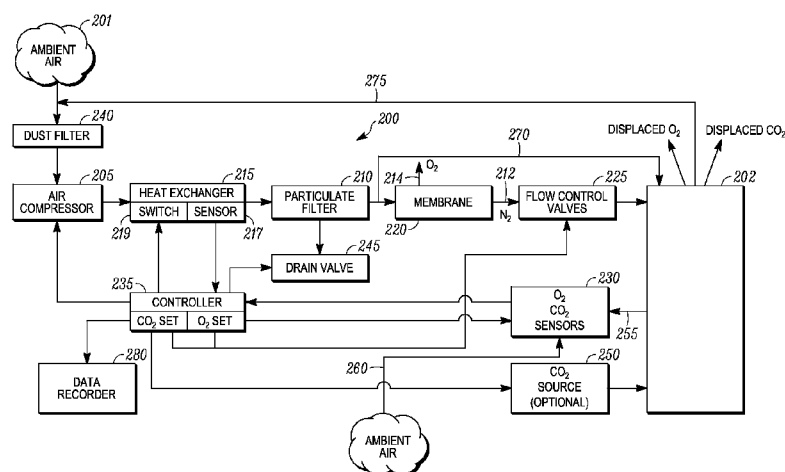


FIG. 2

(57) **Abstract:** A method and system for monitoring a leak rate of a transport unit is provided. The method and system described herein can monitor a leak rate of a transport unit based on CO₂ decay within the transport unit, based on a pressure differential between the storage space of the transport unit and the ambient surrounding the outside of the transport unit, or based on using one or more drains of the transport unit.

METHODS AND SYSTEMS FOR MONITORING A LEAK RATE OF A TRANSPORT UNIT

FIELD

5 Embodiments of this disclosure relate generally to a climate controlled transport unit (CCTU), and more particularly to methods and systems for monitoring a leak rate of a transport unit of the CCTU.

BACKGROUND

10 A controlled atmosphere system (CAS) is generally used to control an atmospheric parameter such as, but not limited to, a nitrogen (N₂) content, an oxygen (O₂) content and/or a carbon dioxide (CO₂) content within a storage space, for example, within a transport unit. Examples of a transport unit include, but are not limited to, a marine container, a container on a flat car, an intermodal container, a truck, a boxcar, or other similar transport unit. A transport
15 unit is commonly used to transport perishable cargo such as, but not limited to, produce, frozen foods, and meat products. By controlling one or more atmospheric parameters within the transport unit, the rate of ripening of perishable cargo stored in the transport unit can be reduced.

SUMMARY

20 Embodiments of this disclosure relate generally to a CAS of a CCTU. More specifically, the embodiments relate to methods and systems for monitoring a leak rate of a transport unit of the CCTU.

 In particular, the embodiments described herein can monitor a leak rate of a transport unit based on CO₂ decay within the transport unit, based on a pressure differential between the
25 storage space of the transport unit and the ambient surrounding the outside of the transport unit, and based on using one or more drains of the transport unit.

 A high leak rate of a transport unit can be undesirable for a CAS. In particular, a high leak rate can result in higher heat loss, increased energy consumption by the CAS, decreased ability to maintain precise temperature and atmosphere control within the transport unit, etc.

30 The embodiments described herein can determine when a leak rate of a transport unit is greater than the level of atmosphere (e.g., the CO₂ level, the O₂ level) that can be supplied by the

CAS. For example, in some embodiments, when the leak rate of a transport unit is determined to be greater than $\sim 2\text{m}^3/\text{hr}$, the transport unit can be determined to be leaky and can be determined to be out of an acceptable range for use with a CAS.

5 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 climate controlled transport unit, with which the embodiments
10 disclosed herein can be practiced.

Fig. 2 is a block diagram of a controlled atmosphere system, according to one embodiment.

Fig. 3 illustrates a flowchart of a method for monitoring a leak rate of a transport unit based on CO_2 level decay, according to one embodiment.

Fig. 4 illustrates a graph showing examples of CO_2 level decay for different storage space
15 leak rates, according to one embodiment.

Fig. 5 illustrates a flowchart of a method for monitoring a leak rate of a transport unit based on a pressure differential between the storage space and the ambient outside of the transport unit, according to one embodiment.

Fig. 6 illustrates a graph showing the pressure difference over time as the storage space
20 reaches a maximum steady state pressure difference.

Figs. 7A and 7B illustrate two different embodiments of a leak rate detection system for a transport unit.

Fig. 8 illustrates a leak rate device for use with a leak rate detection system, according to
25 one embodiment.

Like reference numbers represent like parts throughout.

DETAILED DESCRIPTION

Perishable goods, such as fruits and vegetables, can consume oxygen and produce carbon
30 dioxide (e.g. due to a ripening effect of the perishable goods) when being stored or in transportation. The ripening effect can reduce shelf life of the perishable goods. To help

prolong the shelf life of the 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 the oxygen and/or carbon dioxide in the storage space to change, which may 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.

In many instances, the CAS of a CCTU is required to operate for a long time during transport (e.g., during oversea transport) and maintaining a desired atmosphere (e.g., oxygen level, carbon dioxide level, etc.) within the storage space of the transport unit during this time can be critical in order to maintain the cargo stored within the storage space. If the transport unit is leaky, the controlled atmosphere air within the storage space will be continuously replaced by ambient air surrounding the outside of the transport unit. This can prevent the CAS to maintain the desired atmosphere within the storage space and potentially reduce the efficiency of the CAS.

The leak rate of a transport unit can increase over time due to operation (e.g., handling, transport, etc.) and aging. Over time, the sealing around the transport unit and the doors of the transport unit can degrade. As the leak rate of the transport unit degrades, it can be useful to know when the transport unit may not be adequate to provide controlled atmosphere within the storage space during transport. Accordingly, the embodiments described herein provide methods and systems for monitoring a leak rate of a transport unit.

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.

A “controlled atmosphere system” (CAS) includes, for example, a controlled atmosphere circuit for controlling one or more atmospheric parameters (e.g., oxygen level, carbon dioxide level, etc.) within an interior space of a transport unit. The CAS can include, without limitation, an air compressor, a CO₂ 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.

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 CO₂ filter and the fresh air exchange mechanism.

5 In some embodiments, the CCTU can also include a transport refrigeration system (TRS). 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 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. The TRU can
10 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
15 other embodiments, the TRU and the CAU can be separate units that are each attached to the transport unit.

 A "CAS controller" includes, for example, an electronic device (e.g., a processor, memory, etc.) that is configured to communicate with, manage, command, direct, and regulate the behavior of one or more components of a CAS (e.g., an air compressor, one or more flow
20 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 a power unit powering, for example, the CAS and the TRS, etc.

25 A "transport unit" includes, for example, a trailer (e.g., trailer on flat car, etc.), a container (e.g., container on flat cars, intermodal container, marine container, freight 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. As discussed herein, the transport unit can include insulated walls, doors and floor and is designed
30 to retard the rate of heat of transmission (e.g., ISO 1496-2). The transport unit can be used for transporting frozen or fresh, perishable cargo (e.g., fruits, vegetables, plants, meat, 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 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
 5 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 conditions within the storage space such as e.g., a temperature, a carbon dioxide concentration, an oxygen concentration, etc.

10 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 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
 15 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 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.

20 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 one embodiment of CAS 200 for a transport unit 202, such as the transport unit 130 shown in Fig. 1. The basic components of the CAS include an air compressor 205, a particulate filter 210, a heat exchanger 215, a nitrogen separation membrane 220, a system
 25 of metering valves 225, a plurality of gas sensors 230 and a CAS controller 235.

The CAS 200 is configured to control, for example, 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 (O₂) and carbon dioxide (CO₂) by introducing nitrogen (N₂) generated from the nitrogen separation membrane 220.

30 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. The high pressure air is then filtered by the particulate filter 210 to remove moisture and dirt before passing to the heat exchanger 215. A normally closed drain valve 245 is
5 provided on the particulate filter 210. The drain valve 245 is adapted to be opened 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.

High pressure air from the particulate filter 210 passes to the heat exchanger 215 where it
10 can be temperature conditioned (e.g., heated or cooled) to an optimum operating temperature. The CAS controller 235 receives inputs 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 temperature conditioned, high pressure air passing from the heat exchanger 215
15 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
20 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
25 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
30 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 CO₂ from a CO₂ source 250 if desired. In

some embodiments, the CO₂ source 250 is an internal CO₂ source that can be configured to inject CO₂ within the storage space of the transport unit during transport. In other embodiments, the CO₂ source 250 is an external CO₂ source that can be configured to inject CO₂ within the storage space of the transport unit prior to transport.

5 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.

10 The gas sensors 230 can include, for example, an oxygen concentration sensor, a carbon dioxide concentration sensor, an ethylene concentration sensor, an ozone sensor, a tracer gas 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 CAS 200 including the transport unit 202, a CARU (e.g., the CARU 120
15 shown in Fig. 1), etc.

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.

20 Fig. 3 illustrates a flowchart of a method 300 for monitoring a leak rate of a transport unit (e.g., the transport unit 130 shown in Fig. 1) based on CO₂ level decay. At 305, a CO₂ sensor (e.g., one or more of the gas sensors 230 shown in Fig. 2) is configured to measure an initial CO₂ level within the transport unit and is configured to send initial CO₂ level data to a CAS controller (e.g., the CAS controller 235). The CAS controller then stores the initial CO₂ level data in a
25 memory portion (e.g., the data recorder 280 shown in Fig. 2). The method 300 then proceeds to 310.

At 310, the CAS controller instructs a CO₂ source (e.g., the CO₂ source 250 shown in Fig. 2) to inject CO₂ within the storage space of the transport unit. During this time the CAS controller is configured to monitor the CO₂ level within the storage space via the CO₂ sensor.

30 Once the CAS controller determines that the CO₂ level within the storage space reaches a

setpoint X, the CAS controller instructs the CO₂ source 250 to stop injecting CO₂ into the storage space (315).

The setpoint X can be a system or user defined CO₂ level that can vary based on the volume of the storage space within the transport unit being monitored, the desired amount of time required to calculate the leak rate of the transport unit, the sensitivity of the CO₂ sensor, whether any cargo is stored in the storage space, and the type of cargo stored in the storage space, etc. For example, in one embodiment, when the volume of the storage space within the transport unit is ~67m³, and the desired amount of time required to calculate the leak rate of the transport unit is between ~1 to ~8 hours, the setpoint X can be set to ~1%. It will be appreciated that the higher the setpoint X, the less amount of time required to calculate the leak rate of the transport unit.

At 320, the CO₂ sensor continuously or periodically monitors the CO₂ level within the storage space and sends the monitored CO₂ level data to the CAS controller over a time period T₁. The CAS controller receives the monitored CO₂ level data and stores said data into the memory portion over the time period T₁.

The time period T₁ can be the desired amount of time required to calculate the leak rate of the transport unit. For example, when the setpoint X is set to ~1%, the time period T₁ can be set, for example, to about two hours.

After the time period T₁ has passed, the CAS controller can determine a CO₂ decay based on the monitored CO₂ level data stored in the memory portion. Fig. 4 illustrates a graph 400 with examples of CO₂ decay for different storage space leak rates. The examples shown in the graph 400 are for a storage space having a volume V of ~67m³ and a setpoint X of ~1%.

Based on the CO₂ decay, the CAS controller can determine a leak rate of the transport unit. For example, in some embodiments, the CO₂ leak rate can be determined using the equation:

$$(CO_2)_t = (CO_{2(initial)} / CO_{2(injected)}) * (1 - EXP^{(-leak/V) \cdot t}) + EXP^{(-leak/V) \cdot t}$$

where:

(CO₂)_t = the concentration of CO₂ at time t

CO_{2(initial)} = the initial (e.g., ambient) concentration of CO₂ within the storage space (305)

CO_{2(injected)} = the CO₂ level of setpoint X

V = the volume of the storage space (m³)

$$t = \text{time (hrs)}$$
$$\text{leak} = \text{leak rate (m}^3/\text{hr)}$$

Fig. 5 illustrates a flowchart of a method 500 for monitoring a leak rate of a transport unit (e.g., the transport unit 130 shown in Fig. 1) based on a pressure differential between the storage space of the transport unit and the ambient surrounding the outside of the transport unit, according to one embodiment. In some embodiments, the method 500 can be an operation mode of a CAS (e.g., the CAS 200 shown in Fig. 2). In some embodiments, it is preferable that all doors of the transport unit are closed, any fresh air control mechanism is in a fully closed state, any drain plugs of the transport unit are plugged, and an evaporator drain tube of the transport unit is flooded. Further, in some embodiments, it is preferable that the ambient temperature surrounding the outside of the transport unit is at least 5° Celsius.

At 505, a CAS controller (e.g., the CAS controller 235 shown in Fig. 2) determines a size of the transport unit (e.g., a ~40 ft container, a ~20 ft container, etc.). The size of the transport unit can be used by the CAS controller to determine constant values and a proper calibration curve to be used in the leak rate calculation. In some embodiments, the size of the transport unit can be entered and stored in a memory portion (e.g., the data recorder 280 shown in Fig. 2) via a human machine interface (not shown) of the CAS by a CAS operator. In other embodiments, the size of the transport unit can be entered and stored in the memory portion, 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 510, the CAS controller obtains an ambient temperature of the air surrounding the outside of the transport unit and an internal temperature within the storage space within the transport unit. In some embodiments, the ambient temperature and the internal temperature are obtained using one or more temperature sensors that are part of the CAS and disposed within the storage space and/or an outside portion of the transport unit, and the one or more temperature sensors are configured to send internal temperature data and ambient temperature data to the CAS controller. In some embodiments, the ambient temperature can be sent to the CAS controller via a third party device (e.g., smart phone, tablet, etc.), for example, using a WiFi, Bluetooth, Zigbee, Infrared, etc. connection.

At 515, the CAS controller calculates an absolute temperature difference between the ambient temperature and the internal temperature and determines whether the absolute temperature difference is within a range A. In some embodiments, the range A can be, for example, $\sim 5^{\circ}$ Celsius. If the absolute temperature difference is within the range A, the method
 5 500 proceeds to 525. If not, the method 500 proceeds to 520.

At 520, the CAS controller starts the TRS to control the temperature within the storage space so that the absolute temperature difference is within the range A. Then, the method 500 proceeds back to 515.

At 525, the CAS controller obtains an ambient pressure of the air surrounding the outside
 10 of the transport unit and an internal pressure within the storage space within the transport unit. In some embodiments, the ambient pressure and the internal pressure are obtained using one or more pressure sensors are part of the CAS and disposed within the storage space and/or an outside portion of the transport unit, and the one or more pressure sensors are configured to send internal pressure data and ambient pressure data to the CAS controller. The CAS controller
 15 calculates an initial pressure difference $\Delta p_{\text{initial}}$ based on the internal pressure and the ambient pressure and stores the initial pressure difference $\Delta p_{\text{initial}}$ within a memory portion of the CAS (e.g., the data recorder 280 shown in Fig. 2). The method 500 then proceeds to 530.

At 530, the CAS controller instructs the CAS to supply a known and constant supply air flow rate into the storage space for a time period T_2 in order to create an overpressure situation in
 20 the storage space. In some embodiments, the CAS controller instructs an air compressor of the CAS (e.g., the air compressor 205 shown in Fig. 2) to operate in a ventilation mode to supply the known and constant air flow rate within the storage space. In other embodiments, the CAS controller can instruct an air pump or a vacuum pump of the CAS to supply the known and constant supply air flow rate into the storage space. The time period T_2 is a time period for the
 25 storage space to reach an overpressure situation and reach a maximum steady state pressure difference. In some embodiments, the time period T_2 is ~ 13 minutes. Fig. 6 illustrates a graph 600 showing the pressure difference Δp over time as the storage space reaches a maximum steady state pressure difference.

At 535, the CAS controller monitors the pressure difference between the storage space
 30 and the ambient for a time period T_3 . The CAS controller uses the pressure difference data over the time period T_3 to calculate an average pressure difference ADP. In some embodiments, the

time period T_3 can be ~2 minutes. At 540, the CAS controller stops the supply of the known and constant air flow rate into the storage space.

At 545, the CAS controller determines whether the average pressure difference ADP is less than a minimum pressure threshold Y. In some embodiments, the minimum pressure
 5 threshold Y can be, for example, 3 Pa. If the average pressure difference ADP is less than the minimum pressure threshold Y, the method proceeds to 550. If the average pressure difference ADP is not less than the minimum pressure threshold Y, the method proceeds to 555.

At 550, the CAS controller determines that a leak rate calculation is not possible and that the transport unit has a leak rate that is beyond an acceptable level for CAS operation.

10 At 555, the CAS controller uses the average pressure difference ADP to calculate a leak rate Q using a predetermined calibration curve. The calibration curve is a predetermined curve stored in a memory portion of the CAS controller that is based on, for example, the size of the transport unit, the known and constant supply air flow rate supplied by the CAS at 530, etc. In some embodiments, the calibration curve can be derived based on experimental data. In one
 15 embodiment, the leak rate Q can be determined using the equation:

$$Q = k(ADP \cdot r)^{-f},$$

where k, r and f are predetermined and experimentally derived constant values obtained based on the calibration curve.

At 560, the CAS controller determines whether the leak rate Q is less than a category I
 20 threshold Z_1 . If the leak rate Q is less than the category I threshold Z_1 , the method 500 proceeds to 565. If the leak rate Q is not less than the category I threshold Z_1 , the method 500 proceeds to 570. At 565, the CAS controller determines that the transport unit is a Category I transport unit indicating that the transport unit can provide temperature control and atmosphere control easily and efficiently and can retain desired temperature and atmosphere levels for a longer time than,
 25 for example, Category II or Category III transport units.

At 570, the CAS controller determines whether the leak rate Q is less than a category II
 threshold Z_2 . If the leak rate Q is less than the category II threshold Z_2 , the method 500 proceeds to 575. If the leak rate Q is not less than the category II threshold Z_2 , the method 500 proceeds to 580. At 575, the CAS controller determines that the transport unit is a Category II transport
 30 unit indicating that the transport unit can provide temperature control and atmosphere control, but not as easily and efficiently and cannot retain desired temperature and atmosphere levels as

long as a Category I transport unit. At 580, the CAS controller determines that the transport unit is a Category III transport unit indicating that the transport unit may have difficulty providing temperature control and atmosphere control, and cannot provide temperature and atmosphere control as easily and efficiently and cannot retain desired temperature and atmosphere levels as long as either a Category I transport unit or a Category II transport unit.

It will be appreciated that in some embodiments, the CAS controller need not determine whether the transport unit is a Category I, II or III transport unit. In some embodiments, the CAS controller may use the leak rate Q directly to determine the operability/reliability of the transport unit.

10 An advantage of the method 500, is that the CAS controller can determine a leak rate of the transport unit without need of any additional instrumentation. Also, the leak rate of the transport unit can be provided throughout the lifetime of the transport unit. Accordingly, as the transport unit degrades, the method 500 can determine when the transport unit may be unacceptable for controlled atmosphere and temperature control requirements. Also, the method
15 500 can provide more information regarding the leak rate of the transport unit than the ISO 1496-2 test. Also, the method 500 can be recalculated to ISO 1496-2 airtightness requirements. Moreover, the method 500 can provide pre-trip leak rate calculations that can allow immediate improvement of the tightness of the transport unit if the leak rate calculation is not acceptable, thereby preventing damage to cargo during transport. Further, the method 500 can allow the
20 transport unit to keep required internal atmosphere and temperature requirements with a lower energy consumption of the CAS and the TRS, can allow for lower heat losses and more precise atmosphere and temperature control. Also, the method 500 can calculate the leak rate of the transport unit, for example, in ~10 to ~15 minutes.

Figs. 7A and 7B illustrate different embodiments of a leak rate determination system
25 700, 700' for determining a leak rate of a storage space 707 transport unit 705 using one or more drains 710 of the transport unit 705.

The leak rate determination system 700 shown in Fig. 7A includes the transport unit 705, two open drains 710a,b, closed drains 712, a sampling leak rate device 720a, a dosing leak rate device 720b, and a measurement device 730.

The sampling leak rate device 720a is configured to connect and tightly seal to the drain 710a and the dosing leak rate device 720b is configured to connect and tightly seal to the drain 710b. The closed drains 712 are tightly sealed using, for example, a rubber kazoo.

5 The sampling leak rate device 720a is configured to include a sensor (not shown) for measuring a parameter within the storage space 707 and is connected to the measurement device 730 to send parameter data to the measurement device 730.

The sampling leak rate device 720a and the dosing leak rate device 720b are fluidly and electrically connected to the measurement device 730. The preparation of installing the leak rate devices 720a,b can be, for example, ~15 minutes.

10 As shown in Fig. 8, a transport unit 805 includes a drain 810 that allows a leak rate device 820 to attach thereto. A conventional drain, such as the drain 810, typically can have an inner diameter of about 40 mm and an outer diameter of about 44 mm. The leak rate device 820 can be composed of an elastic material and includes a drain connection portion 822 and a measurement device portion 824. In order to securely fit the leak rate device 820 to the drain
15 810, the drain connection portion 822 can have an inner diameter d that is smaller than the outer diameter of the drain 810 (e.g., smaller than ~44 mm). The outer diameter of the measurement device portion 824 can vary based on the type of measurement device (e.g., the measurement device 730 shown in Figs. 7A and 7B) being connected thereto. The leak rate device 820 can be a low cost fixture and can be universal and suitable for usage in all types of transport units.

20 Returning to Fig. 7, the measurement device 730 is configured to operate a leak rate test using the dosing leak rate device 720b to supply a fluid or gas into the storage space 707 and using the sampling leak rate device 720a to measure a parameter within the storage space 707. The measurement device 730 can include a processor, a memory, a clock, and an input/output (I/O) interface (not shown) to run the leak rate test. The leak rate test can be one or more of a
25 pressure increase test, a pressure decay test, a tracer gas decay test, a constant injection test, a constant concentration test, etc.

In some embodiments, the measurement device 730 can apply a pressure increase test to determine the leak rate. In these embodiments, the measurement device 730 can include an air compressor (not shown) that can supply a known and constant air flow rate through the dosing
30 leak rate device 720b. In these embodiments, the measurement device 730 can obtain an initial pressure within the storage space 707 from the sampling leak rate device 720a. The

measurement device 730 can then supply compressed air from the air compressor for a time period (e.g., ~15 minutes) and then use the sampling leak rate device 720a to sample a post pressure within the storage space 707 after the time period. The measurement device 730 can determine a leak rate for the transport unit 705 based on the initial pressure and the post pressure
5 using a leak rate method (e.g., the leak rate method 500 shown in Fig. 5).

In some embodiments, the measurement device 730 can apply a pressure decay test to determine the leak rate. In these embodiments, the measurement device 730 can include an air compressor (not shown) that can supply an air flow rate high enough to create an overpressure situation within the storage space 707 (e.g., ~5 to ~30 m³/hr) through the dosing leak rate device
10 720b. Once the measurement device 730 and the sampling leak rate device 720a determines that a selected pressure within the storage space 707 is reached (e.g., ~500 to ~1000 Pa), the air compressor is turned off and a time period is measured for the measurement device 730 and the sampling leak rate device 720a to determine that the pressure storage space 707 has reached a second pressure level (e.g., 200 Pa). Based on the measured time period, the measurement
15 device 730 can calculate the leak rate of the transport unit 705.

In some embodiments, the measurement device 730 can apply a tracer gas decay test to determine the leak rate. In these embodiments, the measurement device 730 can include a tracer gas source (e.g., a CO₂ source) that can supply an inert gas (e.g., CO₂) through the dosing leak rate device 720b into the storage space 707. In these embodiments, the sampling leak rate device
20 720a can monitor the inert gas level within the storage space 707 and send the monitored inert gas data to the measurement device 730. The measurement device 730 can supply inert gas from the inert gas source until the measurement device 730 determines that the inert gas level in the storage space reaches a preset value (e.g., ~1%). The measurement device 730 can then determine a leak rate for the transport unit 705 by monitoring a inert gas decay for a time period
25 (e.g., ~1 to ~8 hours) within the storage space 707 using a leak rate method (e.g., the leak rate method 300 shown in Fig. 3).

In some embodiments, the measurement device 730 can apply a constant injection test to determine the leak rate. In these embodiments, the measurement device 730 can include a tracer gas source (e.g., a CO₂ source) that can supply a constant supply and air flow rate of an inert gas
30 (e.g., CO₂) through the dosing leak rate device 720b into the storage space 707. In these embodiments, the sampling leak rate device 720a can monitor the inert gas level within the

storage space 707 and send the monitored inert gas data to the measurement device 730. The measurement device 730 can then determine a leak rate for the transport unit 705 by monitoring reached concentration values of the inert gas within the storage space 707 by analyzing, for example, build-up of the achieved inert gas concentration due to a known supply of the inert gas
5 flow rate.

In some embodiments, the measurement device 730 can apply a constant concentration test to determine the leak rate. In these embodiments, the measurement device 730 can include a tracer gas source (e.g., a CO₂ source) that can supply a constant supply and air flow rate of an inert gas (e.g., CO₂) through the dosing leak rate device 720b into the storage space 707. In
10 these embodiments, the sampling leak rate device 720a can monitor the inert gas level within the storage space 707 and send the monitored inert gas data to the measurement device 730. The measurement device 730 can then determine a leak rate for the transport unit 705 by monitoring the amount of inert gas required to be injected within the storage space 707 to maintain a constant concentration of the inert gas within the storage space 707.

15 It will be appreciated that the above listed tests are non-limiting, and other tests could be applied by the measurement device 730 to determine the leak rate within the storage space 707.

The leak rate determination system 700' shown in Fig. 7B is similar to the leak rate determination system 700. The leak rate determination system 700' includes a single open drain 710 and only one leak rate device 720 required. The leak rate device 720 can be used for both
20 dosing and sampling.

An advantage of the leak rate determination systems 700, 700' is that simple leak testing for any conventional transport unit can be completed, even when the storage space 707 is loaded and/or not accessible via, for example, a transport refrigeration unit, a fresh air exchange mechanism, etc. and when leak rate testing is not possible via a CAS. Moreover, the leak rate
25 determination systems 700, 700' are non-invasive (e.g., does not break any tightening and/or security measures) and can easily be performed in field conditions. The leak rate determination systems 700, 700' can also use different test methods (e.g., pressure increase, pressure decay, tracer gas decay, constant injection, constant concentration, etc.) for determining the leak rate of the transport unit. The leak rate determination systems 700, 700' test procedures can be quickly
30 prepared by any skilled technician and requires an inexpensive leak rate device that can be used on all types of transport units.

Aspects:

It is noted that any of aspects 1-3 below can be combined with any of aspects 4-20. Also, any of aspects 4-10 can be combined with any of aspects 11-20.

- 5 Aspect 1. A method for monitoring a leak rate of a transport unit comprising:
 measuring, via a carbon dioxide sensor, an initial carbon dioxide level within the
 transport unit;
 sending the initial carbon dioxide level to a controller;
 injecting carbon dioxide into the transport unit until a carbon dioxide setpoint level is
 10 reached;
 the controller monitoring a carbon dioxide level within the transport unit over a time
 period T;
 the controller determining a leak rate of the transport unit based on the monitored carbon
 dioxide level within the transport unit over the time period T.
- 15 Aspect 2. The method of aspect 1, wherein determining the leak rate of the transport unit
 based on the monitored carbon dioxide level within the transport unit over the time period T
 includes the controller determining a carbon dioxide decay of the transport unit.
- 20 Aspect 3. The method of any one of aspects 1-2, wherein the controller determining the leak
 rate of the transport unit using the equation:

$$(CO_2)_t = (CO_{2(initial)} / CO_{2(injected)}) * (1 - EXP^{(-leak/V) \cdot t}) + EXP^{(-leak/V) \cdot t}$$

 wherein $(CO_2)_t$ is a concentration of carbon dioxide within the transport unit at a time t, $CO_{2(initial)}$
 is the initial carbon dioxide level within the transport unit, $CO_{2(injected)}$ is the carbon dioxide
 25 setpoint level, V is a volume of the storage space, and leak is the leak rate of the transport unit.
- Aspect 4. A method for monitoring a leak rate of a transport unit comprising:
 a controller calculating an absolute temperature difference between an ambient
 temperature of ambient air surrounding an outside of the transport unit and an internal
 30 temperature of internal air within the transport unit;

when an absolute temperature difference between the ambient temperature and the internal temperature is within a maximum threshold, supplying an air flow into the transport unit until a maximum steady state pressure difference between an ambient pressure of the ambient air and an internal pressure of the internal air is reached;

- 5 after reaching the maximum steady state pressure, monitoring a pressure difference between the ambient air and the internal air for a time period T;
 calculating an average pressure difference between the ambient air and the internal air based on the monitored pressure difference for the time period T;
 determining the leak rate based on the average pressure difference.

10

Aspect 5. The method of aspect 4, wherein the controller determining the leak rate of the transport unit using the equation:

$$Q = k(ADP \cdot r)^f,$$

where Q is the leak rate, ADP is the average pressure difference and k, r and f are predetermined
 15 constants.

Aspect 6. The method of any one of aspects 4-5, further comprising:

- measuring the ambient temperature of ambient air surrounding an outside of the transport unit;
 20 measuring the internal temperature of internal air within the transport unit;
 wherein the controller calculating the absolute temperature difference based on the measured ambient temperature and the measured internal temperature.

- Aspect 7. The method of any one of aspects 4-6, wherein supplying the air flow into the
 25 transport unit until the maximum steady state pressure difference between the ambient pressure of the ambient air and the internal pressure of the internal air is reached includes operating an air compressor in a ventilation mode to supply the air flow.

- Aspect 8. The method of any one of aspects 4-6, wherein supplying the air flow into the
 30 transport unit until the maximum steady state pressure difference between the ambient pressure

of the ambient air and the internal pressure of the internal air is reached includes operating at least one of an air pump and a vacuum pump to supply the air flow.

Aspect 9. The method of any one of aspects 4-8, further comprising:

- 5 when the absolute temperature difference is greater than the maximum threshold, providing temperature control within the transport unit until the absolute temperature difference is within the maximum threshold.

Aspect 10. The method of any one of aspects 4-9, further comprising:

- 10 the controller determining an efficiency of the transport unit to provide temperature control and atmosphere control based on the determined leak rate.

Aspect 11. A method for monitoring a leak rate of a transport unit comprising:

- 15 supplying, via a dosing leak rate device, at least one of a fluid and a gas into the transport unit;
monitoring, via a sampling leak rate device, a parameter within the transport unit;
determining the leak rate of the transport unit based on the monitored parameter over a time period T.

- 20 Aspect 12. The method of aspect 11, further comprising a measurement device applying a leak rate test to determine the leak rate based on the monitored parameter over the time period T.

- Aspect 13. The method of aspect 12, wherein the leak rate test is one or more of a pressure increase test, a pressure decay test, a tracer gas decay test, a constant injection test, and a
25 constant concentration test.

Aspect 14. The method of any one of aspects 11-13, wherein the dosing leak rate device and the sampling leak rate device are formed as a single leak rate device.

Aspect 15. The method of any one of aspects 11-14, wherein at least one of the dosing leak rate device and the sampling leak rate device are connected and tightly sealed to a drain of the transport unit.

5 Aspect 16. The method of any one of aspects 11-15, wherein supplying, via the dosing leak rate device, at least one of the fluid and the gas into the transport unit includes supplying, via an air compressor, a compressed air flow into the transport unit for a time period T, and the method further including:

10 determining an initial pressure within the transport unit prior to supplying the compressed air flow based on the monitored parameter;
determining a post pressure within the transport unit upon supplying the compressed air flow for the time period T; and
a measurement device calculating the leak rate based on the initial pressure and the post pressure.

15 Aspect 17. The method of any one of aspects 11-15, wherein supplying, via the dosing leak rate device, at least one of the fluid and the gas into the transport unit includes supplying, via an air compressor, a compressed air flow into the transport unit, and the method further including:

20 supplying, via the dosing leak rate device, the air flow at a rate sufficient to create an overpressure situation within the transport unit by reaching a first pressure level;
monitoring a pressure within the transport unit, via the sampling leak rate device;
when the monitored pressure within the transport unit reaches a second pressure level, determining the time T for the pressure within the transport unit to decay from the first pressure level to the second pressure level; and
25 a measurement device calculating the leak rate based on the determined time period T.

Aspect 18. The method of any one of aspects 11-15, wherein supplying, via the dosing leak rate device, at least one of the fluid and the gas into the transport unit includes supplying, via an inert gas source, an inert gas into the transport unit, and the method further including:

30 supplying, via the dosing leak rate device, the inert gas within the transport unit until an inert gas level within the transport unit reaches a first level;

after supplying the inert gas, monitoring an inert gas decay for the time period T via the sampling leak rate device;

a measurement device calculating the leak rate based on the monitored inert gas decay over the time period T.

5

Aspect 19. The method of any one of aspects 11-15, wherein supplying, via the dosing leak rate device, at least one of the fluid and the gas into the transport unit includes supplying, via an inert gas source, an inert gas into the transport unit, and the method further including:

supplying a constant flow of the inert gas within the transport unit via the dosing leak rate device;

monitoring an inert gas level via the sampling leak rate device;

a measurement device calculating the leak rate based on the monitored inert gas level reaching a set threshold level.

Aspect 20. The method of any one of aspects 11-15, where supplying, via the dosing leak rate device, at least one of the fluid and the gas into the transport unit includes supplying, via an inert gas source, an inert gas into the transport unit, and the method further including:

supplying a flow of the inert gas within the transport unit via the dosing leak rate device;

monitoring an inert gas level via the sampling leak rate device;

a measurement device calculating the leak rate based on an amount of inert gas required to be supplied within the transport unit to maintain a constant concentration of the inert gas within the transport unit.

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. 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
5 true scope and spirit of the disclosure being indicated by the claims that follow.

CLAIMS

1. A method for monitoring a leak rate of a transport unit comprising:
 measuring, via a carbon dioxide sensor, an initial carbon dioxide level within the transport unit;
 5 sending the initial carbon dioxide level to a controller;
 injecting carbon dioxide into the transport unit until a carbon dioxide setpoint level is reached;
 the controller monitoring a carbon dioxide level within the transport unit over a time period T;
 10 the controller determining a leak rate of the transport unit based on the monitored carbon dioxide level within the transport unit over the time period T.
2. The method of claim 1, wherein determining the leak rate of the transport unit based on the monitored carbon dioxide level within the transport unit over the time period T includes the
 15 controller determining a carbon dioxide decay of the transport unit.
3. The method of claim 1, wherein the controller determining the leak rate of the transport unit using the equation:

$$(CO_2)_t = (CO_{2(initial)} / CO_{2(injected)}) * (1 - EXP^{(-leak/V) \cdot t}) + EXP^{(-leak/V) \cdot t}$$
 20 wherein $(CO_2)_t$ is a concentration of carbon dioxide within the transport unit at a time t, $CO_{2(initial)}$ is the initial carbon dioxide level within the transport unit, $CO_{2(injected)}$ is the carbon dioxide setpoint level, V is a volume of the storage space, and leak is the leak rate of the transport unit.
4. A method for monitoring a leak rate of a transport unit comprising:
 25 a controller calculating an absolute temperature difference between an ambient temperature of ambient air surrounding an outside of the transport unit and an internal temperature of internal air within the transport unit;
 when an absolute temperature difference between the ambient temperature and the internal temperature is within a maximum threshold, supplying an air flow into the transport unit
 30 until a maximum steady state pressure difference between an ambient pressure of the ambient air and an internal pressure of the internal air is reached;

after reaching the maximum steady state pressure, monitoring a pressure difference between the ambient air and the internal air for a time period T;

calculating an average pressure difference between the ambient air and the internal air based on the monitored pressure difference for the time period T;

5 determining the leak rate based on the average pressure difference.

5. The method of claim 4, wherein the controller determining the leak rate of the transport unit using the equation:

$$Q = k(ADP * r)^{-f},$$

10 where Q is the leak rate, ADP is the average pressure difference and k, r and f are predetermined constants.

6. The method of claim 4, further comprising:

15 measuring the ambient temperature of ambient air surrounding an outside of the transport unit;

measuring the internal temperature of internal air within the transport unit;

wherein the controller calculating the absolute temperature difference based on the measured ambient temperature and the measured internal temperature.

20 7. The method of claim 4, wherein supplying the air flow into the transport unit until the maximum steady state pressure difference between the ambient pressure of the ambient air and the internal pressure of the internal air is reached includes operating an air compressor in a ventilation mode to supply the air flow.

25 8. The method of claim 4, wherein supplying the air flow into the transport unit until the maximum steady state pressure difference between the ambient pressure of the ambient air and the internal pressure of the internal air is reached includes operating at least one of an air pump and a vacuum pump to supply the air flow.

30 9. The method of claim 4, further comprising:

when the absolute temperature difference is greater than the maximum threshold, providing temperature control within the transport unit until the absolute temperature difference is within the maximum threshold.

- 5 10. The method of claim 4, further comprising:
the controller determining an efficiency of the transport unit to provide temperature control and atmosphere control based on the determined leak rate.
- 10 11. A method for monitoring a leak rate of a transport unit comprising:
supplying, via a dosing leak rate device, at least one of a fluid and a gas into the transport unit;
monitoring, via a sampling leak rate device, a parameter within the transport unit;
determining the leak rate of the transport unit based on the monitored parameter over a time period T.
- 15 12. The method of claim 11, further comprising a measurement device applying a leak rate test to determine the leak rate based on the monitored parameter over the time period T.
- 20 13. The method of claim 12, wherein the leak rate test is one or more of a pressure increase test, a pressure decay test, a tracer gas decay test, a constant injection test, and a constant concentration test.
- 25 14. The method of claim 11, wherein the dosing leak rate device and the sampling leak rate device are formed as a single leak rate device.
15. The method of claim 11, wherein at least one of the dosing leak rate device and the sampling leak rate device are connected and tightly sealed to a drain of the transport unit.
- 30 16. The method of claim 11, wherein supplying, via the dosing leak rate device, at least one of the fluid and the gas into the transport unit includes supplying, via an air compressor, a compressed air flow into the transport unit for a time period T, and the method further including:

determining an initial pressure within the transport unit prior to supplying the compressed air flow based on the monitored parameter;

determining a post pressure within the transport unit upon supplying the compressed air flow for the time period T; and

5 a measurement device calculating the leak rate based on the initial pressure and the post pressure.

17. The method of claim 11, wherein supplying, via the dosing leak rate device, at least one of the fluid and the gas into the transport unit includes supplying, via an air compressor, a
10 compressed air flow into the transport unit, and the method further including:

supplying, via the dosing leak rate device, the air flow at a rate sufficient to create an overpressure situation within the transport unit by reaching a first pressure level;

monitoring a pressure within the transport unit, via the sampling leak rate device;

when the monitored pressure within the transport unit reaches a second pressure level,

15 determining the time T for the pressure within the transport unit to decay from the first pressure level to the second pressure level; and

a measurement device calculating the leak rate based on the determined time period T.

18. The method of claim 11, wherein supplying, via the dosing leak rate device, at least one
20 of the fluid and the gas into the transport unit includes supplying, via an inert gas source, an inert gas into the transport unit, and the method further including:

supplying, via the dosing leak rate device, the inert gas within the transport unit until an inert gas level within the transport unit reaches a first level;

25 after supplying the inert gas, monitoring an inert gas decay for the time period T via the sampling leak rate device;

a measurement device calculating the leak rate based on the monitored inert gas decay over the time period T.

19. The method of claim 11, wherein supplying, via the dosing leak rate device, at least one
30 of the fluid and the gas into the transport unit includes supplying, via an inert gas source, an inert gas into the transport unit, and the method further including:

supplying a constant flow of the inert gas within the transport unit via the dosing leak rate device;

monitoring an inert gas level via the sampling leak rate device;

a measurement device calculating the leak rate based on the monitored inert gas level

5 reaching a set threshold level.

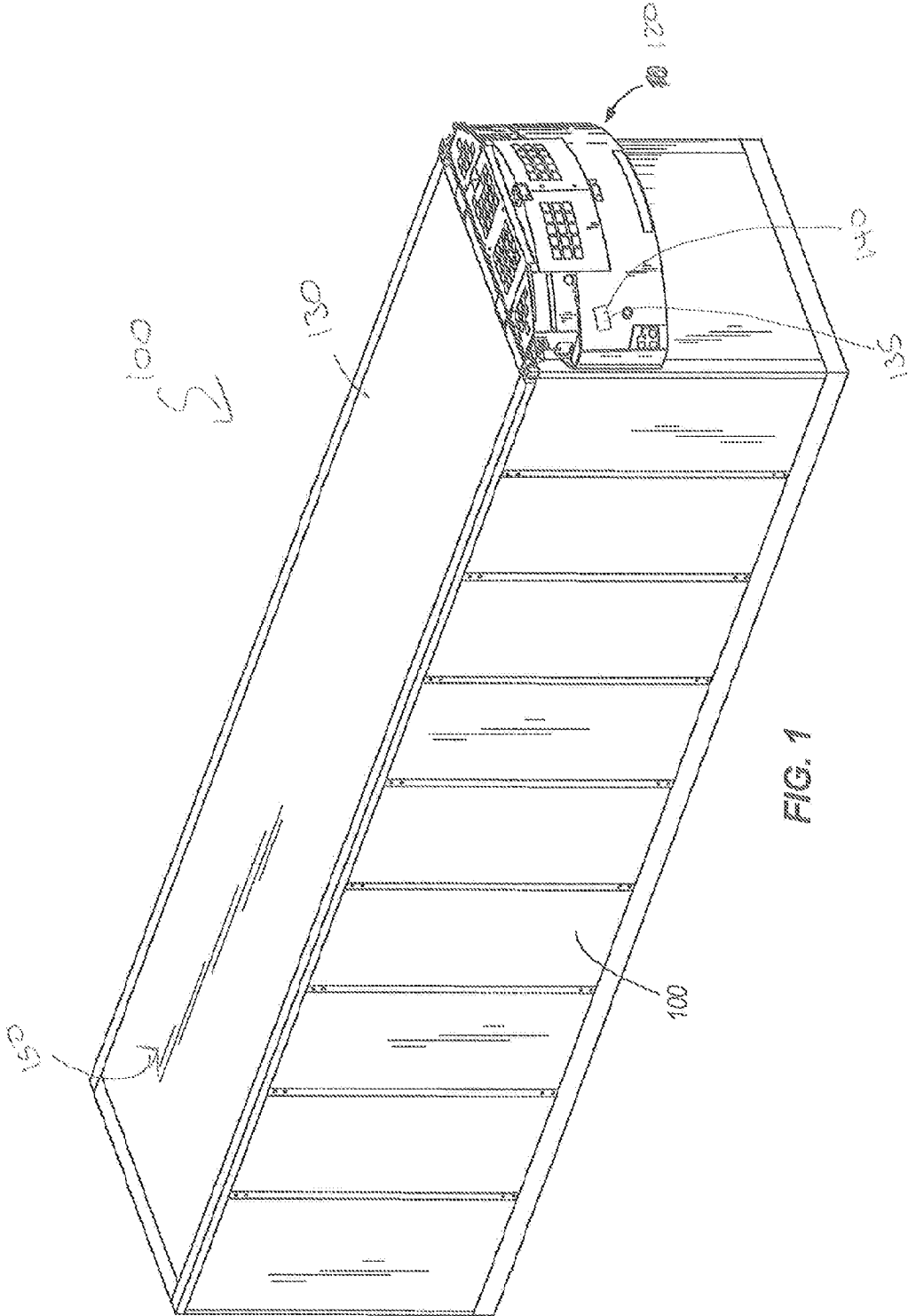
20. The method of claim 11, where supplying, via the dosing leak rate device, at least one of the fluid and the gas into the transport unit includes supplying, via an inert gas source, an inert gas into the transport unit, and the method further including:

10 supplying a flow of the inert gas within the transport unit via the dosing leak rate device;

monitoring an inert gas level via the sampling leak rate device;

a measurement device calculating the leak rate based on an amount of inert gas required to be supplied within the transport unit to maintain a constant concentration of the inert gas within the transport unit.

15



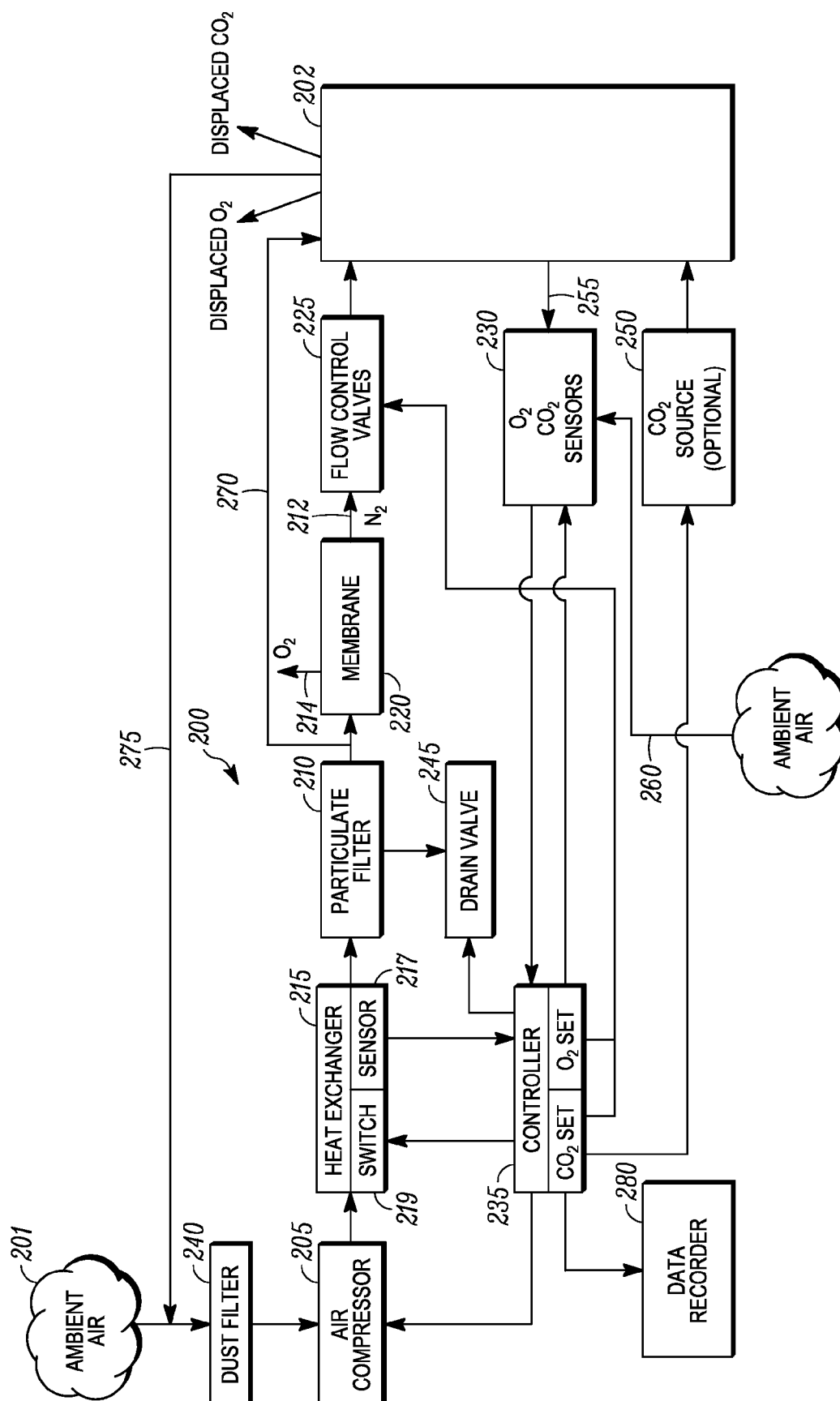


FIG. 2

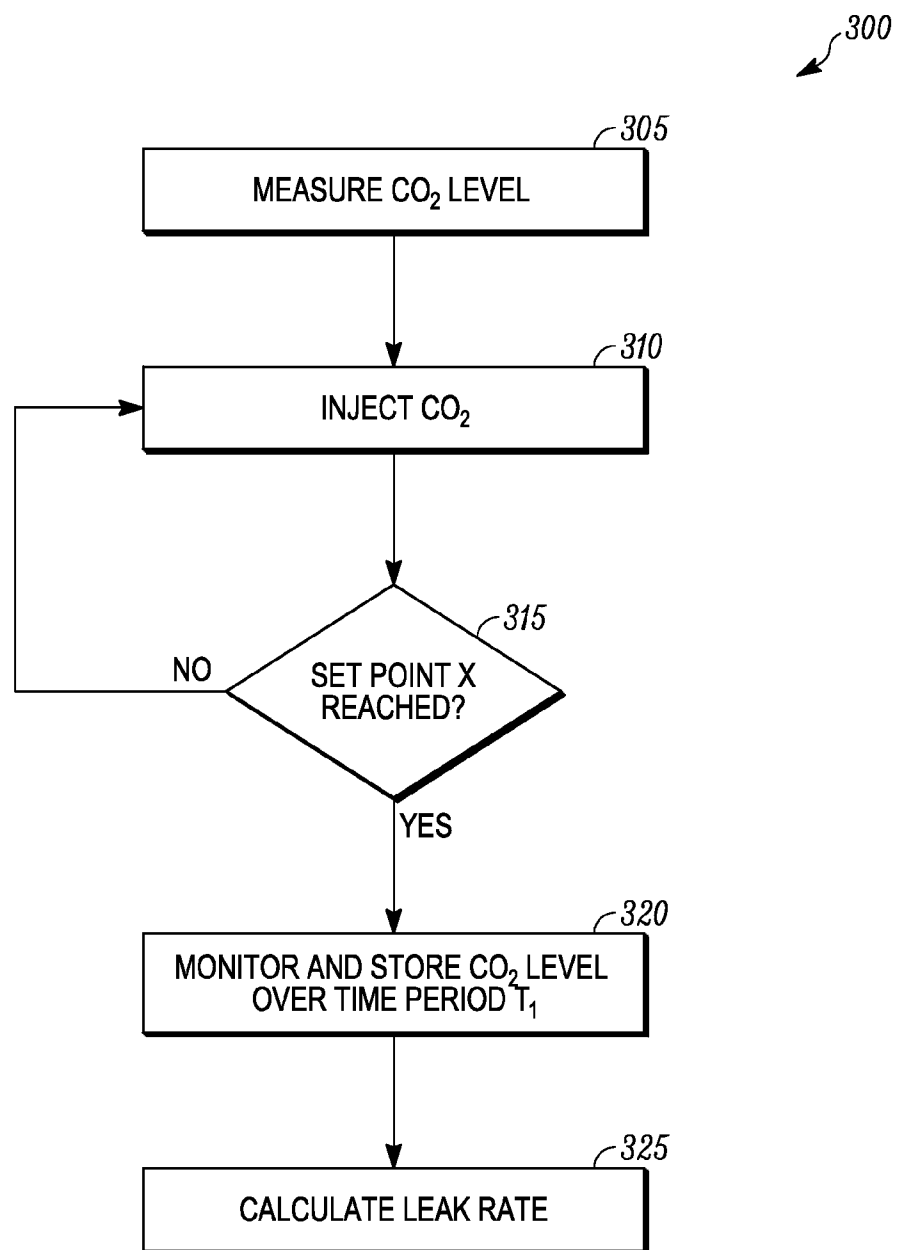


FIG. 3

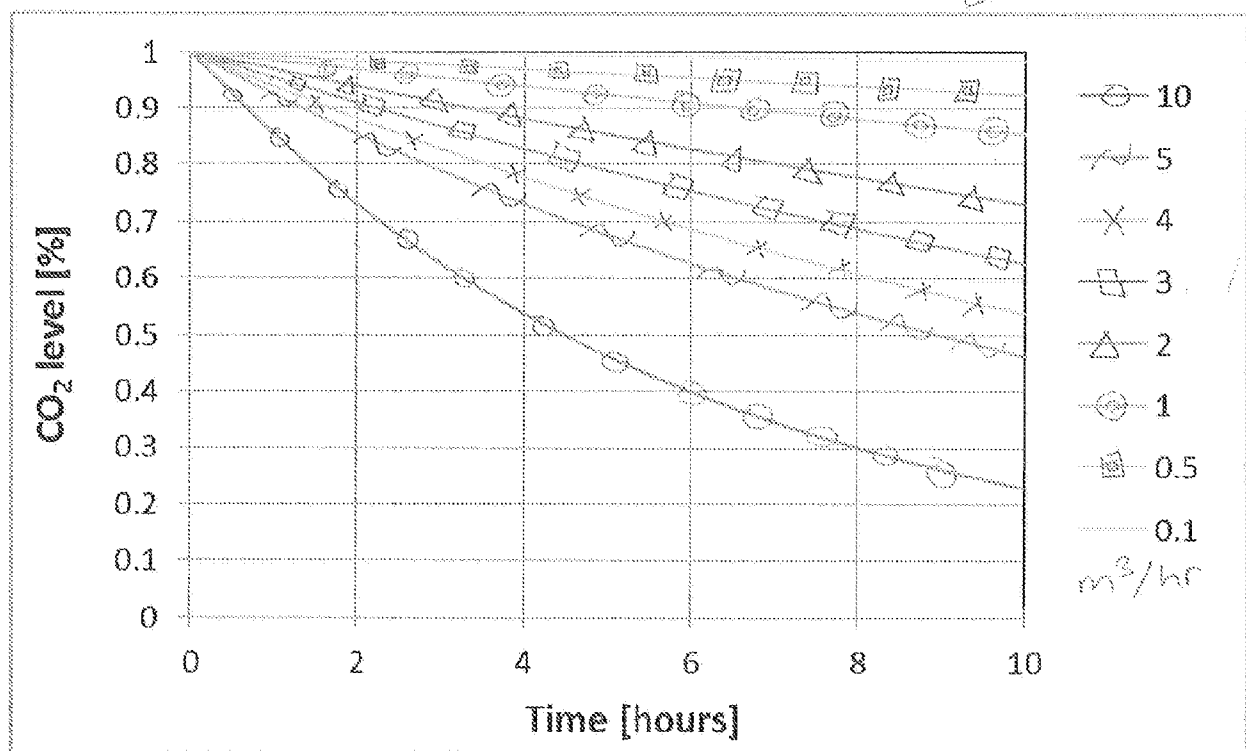


Fig. 4: Examples of CO₂ decay (Injected CO₂ ≈ 4%) for different cargo space leak rates (cargo space ≈ 67 m³)

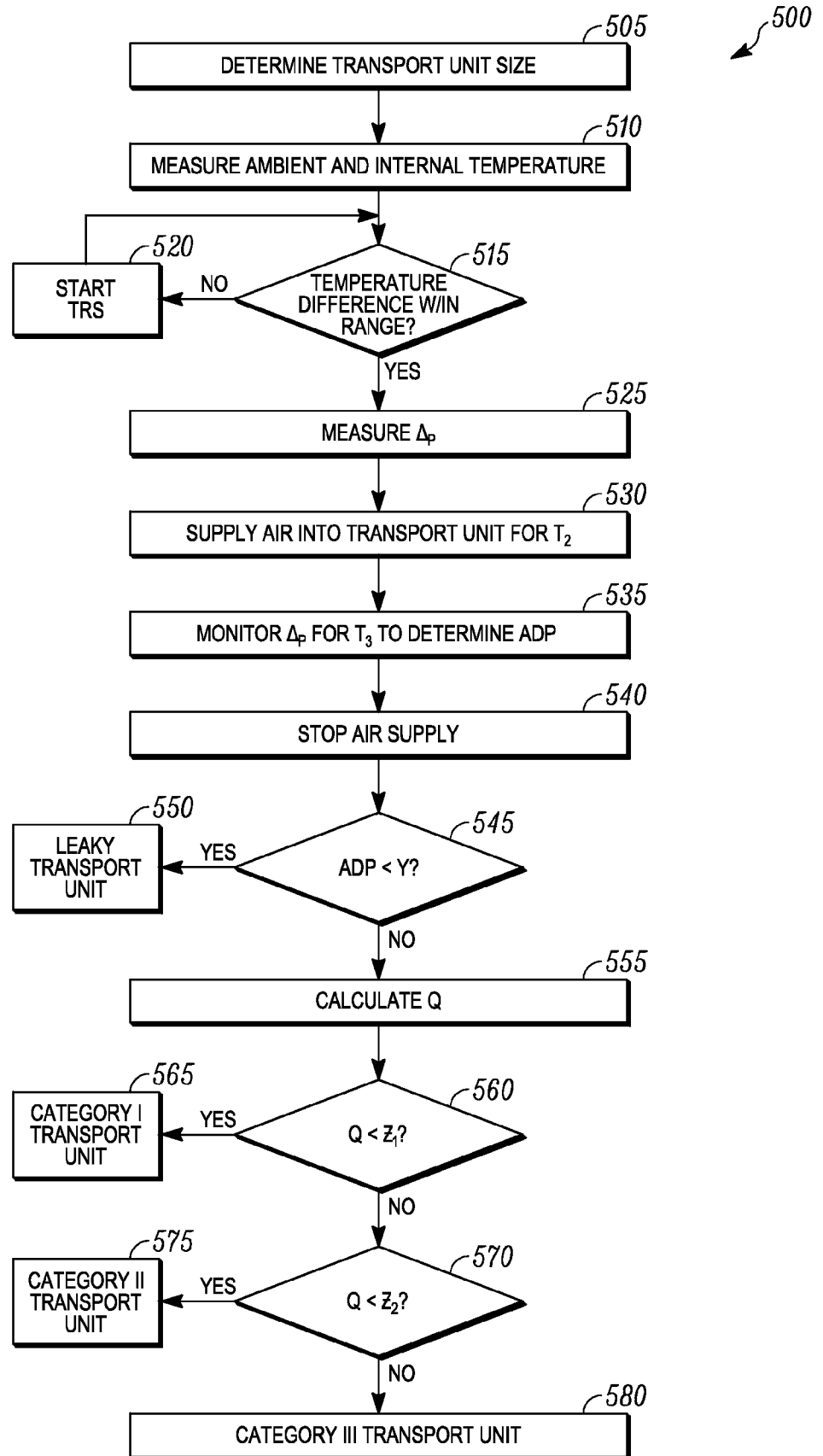
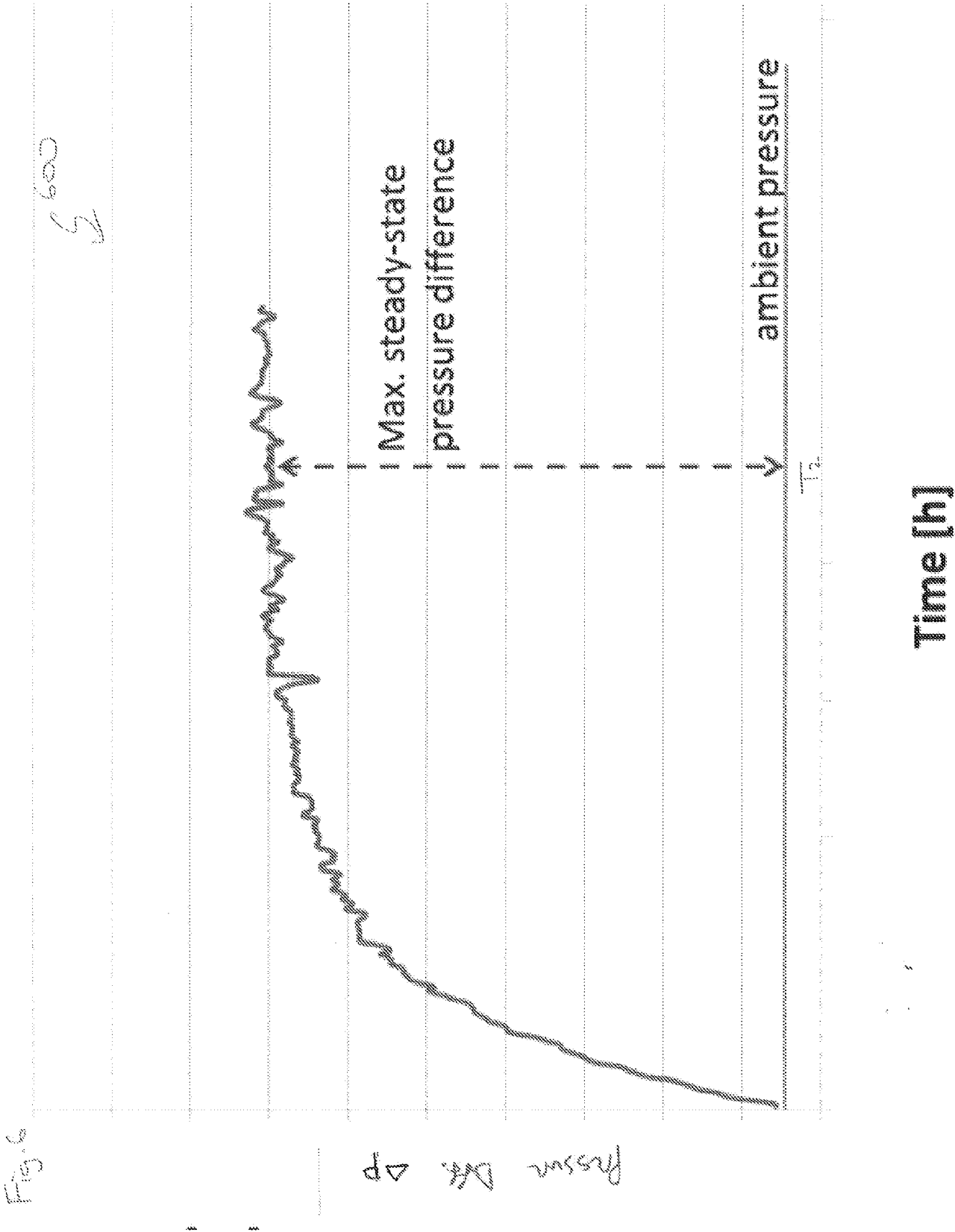
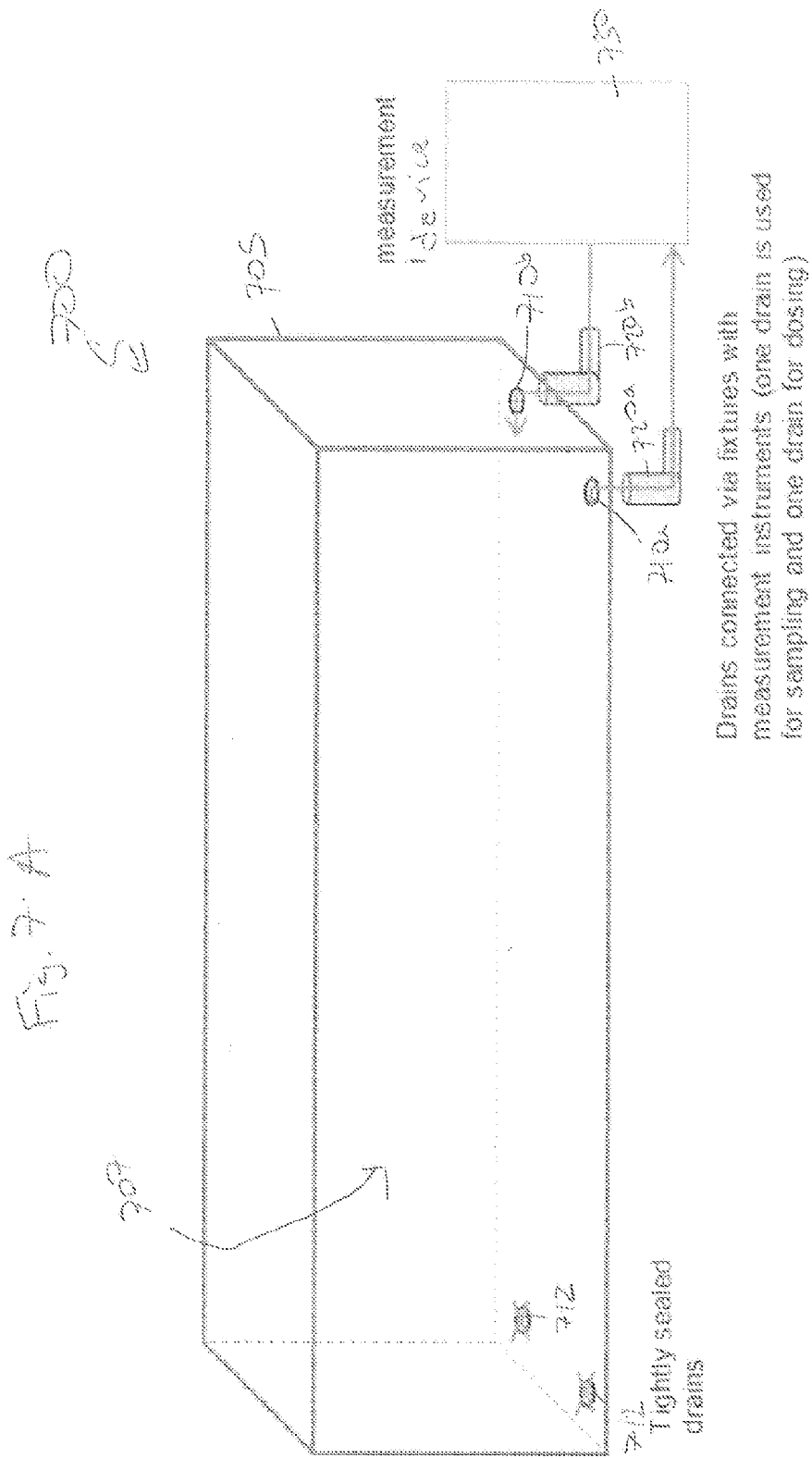


FIG. 5





(c) An example of the drain arrangement for the test (the selection of tightened or connected drains can vary according to the measurement requirements)

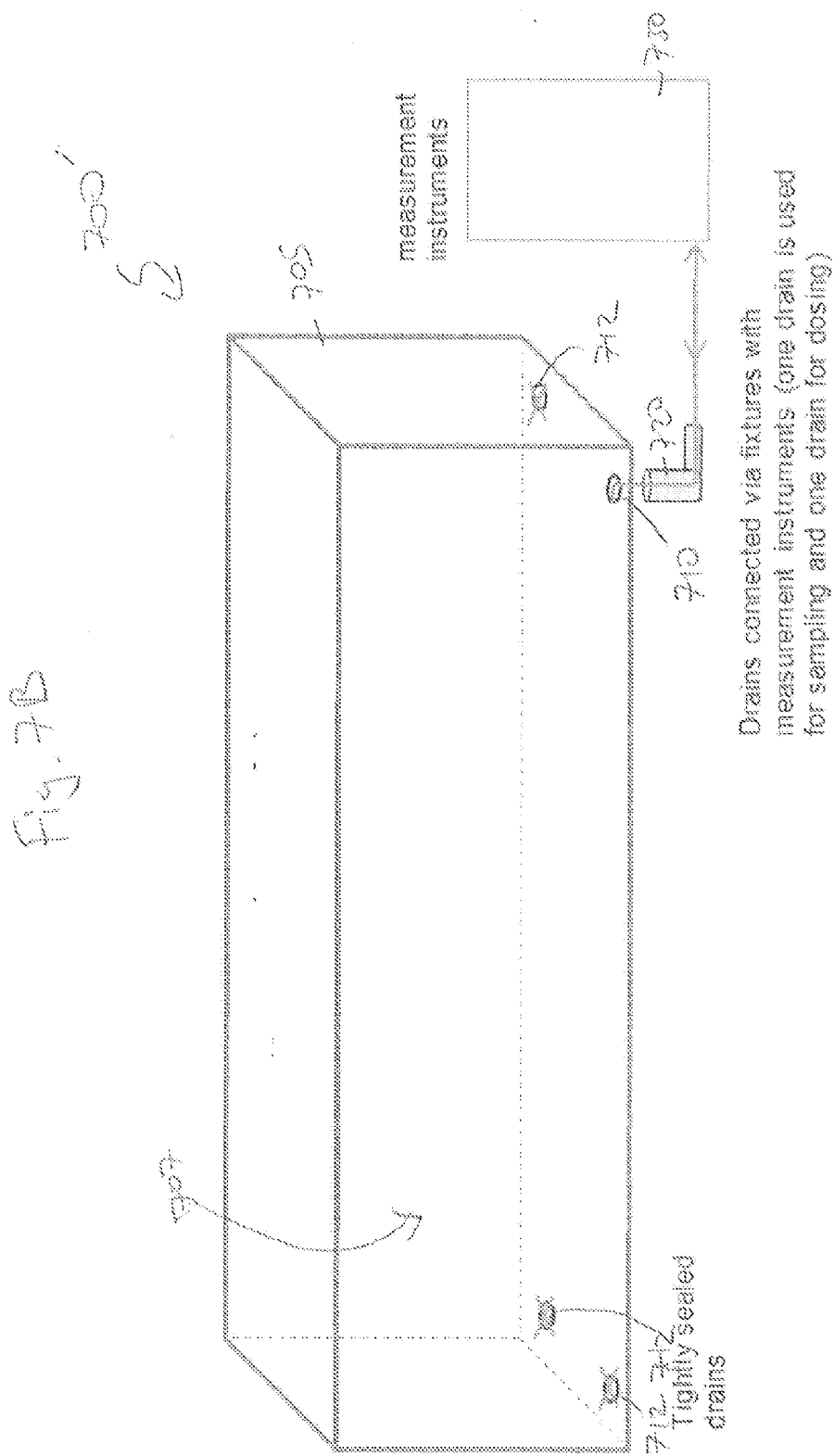


Fig. 7B: Another example of the drain arrangement for the test (in this case only one drain is used for both dosing and sampling)

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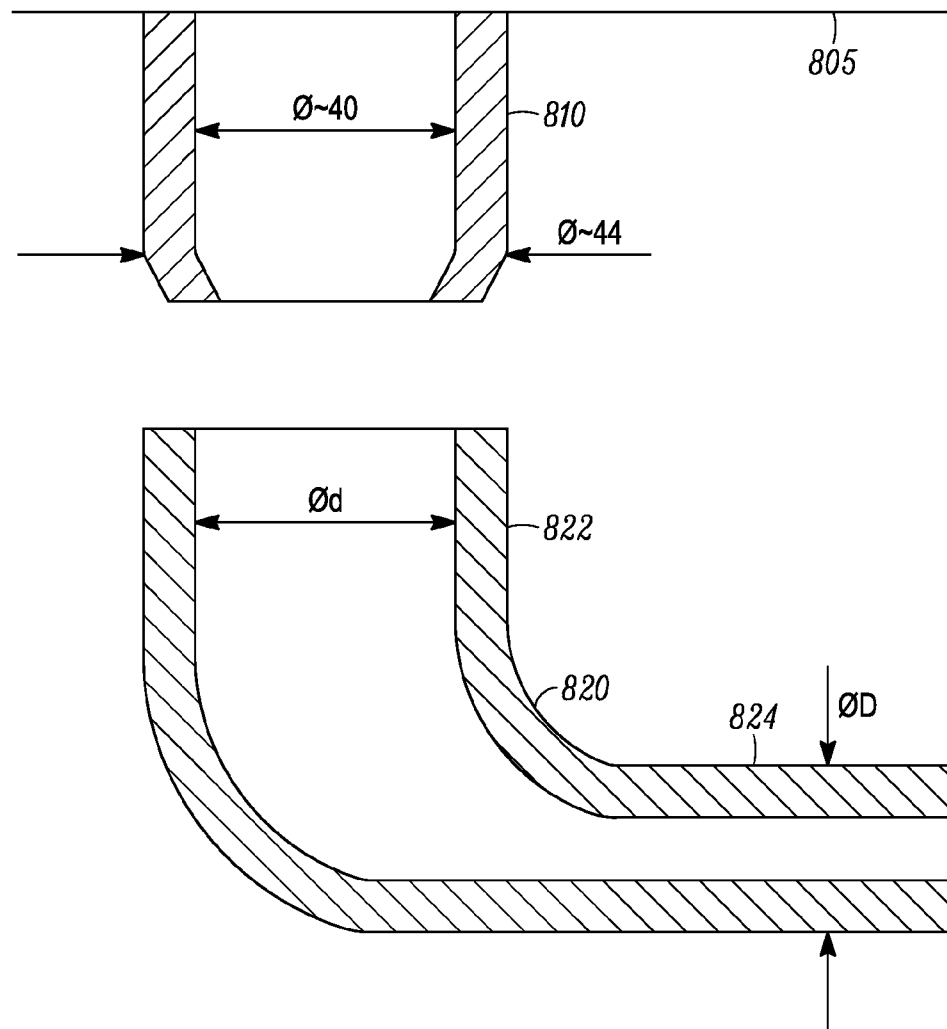


FIG. 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/035431**A. CLASSIFICATION OF SUBJECT MATTER****G01M 3/20(2006.01)i, G01M 3/32(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)

G01M 3/20; B65D 81/18; G05D 27/02; G05B 15/00; F24F 3/16; A61L 9/00; A23L 3/00; G01M 3/32

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: climate controlled transport unit, refrigeration, carbon dioxide, pressure difference and leak**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5457963 A (BARRY P CAHILL-O'BRIEN et al.) 17 October 1995 See abstract, column 4, line 5 - column 8, line 41, column 14, lines 33-46, claims 1-7 and figures 1-17.	1-3, 11-15, 18-20
Y		4-10, 16-17
Y	US 5438841 A (BARRY P CAHILL-O'BRIEN et al.) 08 August 1995 See abstract, column 10, line 40 - column 14, line 67, claim 1 and figures 9A-9E.	4-10, 16-17
A	US 5623105 A (MAX D LISTON et al.) 22 April 1997 See abstract, column 8, line 3 - column 10, line 29, claims 1-3 and figures 1-8.	1-20
A	WO 2014-066952 A1 (MITSUBISHI AUSTRALIA LIMITED) 08 May 2014 See abstract, paragraphs [0087]-[0107], [0114]-[0119] and figures 1-8.	1-20
A	US 2013-0271290 A (JORGE SAENZ et al.) 17 October 2013 See abstract, paragraphs [0031]-[0039], [0064]-[0083] and figures 1-7.	1-20



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

"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

"&" document member of the same patent family

Date of the actual completion of the international search

25 September 2015 (25.09.2015)

Date of mailing of the international search report

25 September 2015 (25.09.2015)

Name and mailing address of the ISA/KR

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2015/035431

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 05457963 A	17/10/1995	CN 1060131 C CN 1118759 A CN 1118759 C EP 0687966 A2 EP 0687966 B1 JP 02635536 B2 JP 08-000168 A	03/01/2001 20/03/1996 20/03/1996 20/12/1995 16/01/2002 30/07/1997 09/01/1996
US 05438841 A	08/08/1995	CN 1048949 C CN 1119612 A CN 1119612 C EP 0688508 A1 EP 0688508 B1 JP 02635534 B2 JP 08-000166 A	02/02/2000 03/04/1996 03/04/1996 27/12/1995 02/08/2000 30/07/1997 09/01/1996
US 05623105 A	22/04/1997	US 05801317 A US 06092430 A	01/09/1998 25/07/2000
WO 2014-066952 A1	08/05/2014	None	
US 2013-0271290 A1	17/10/2013	None	