

**Module and method for providing an inert environment in a sealable container  
and a sealable container**

Technical Field

5 The present disclosure relates to a module and method for providing an inert environment in a sealable container and a sealable container.

Background

10 Transportation using a multimodal container or a shipping container is one of the most popular methods for shipping goods around the world. This popularity is driven by the ease with which cargo sellers and buyers can load and unload these containers themselves, and the reduced costs and increased efficiencies that unitising cargoes in such a way can bring to carriers.

15 This method, however, does have some disadvantages. First, declaring the type of cargo and the loading of it are typically the responsibilities of the cargo owner and as such, the container carrier relies completely on the cargo owner for these details to be accurate and the stowage to be appropriate. Second, the actual cargo and its condition are unknown once the container is sealed after its loading. Therefore, if a dangerous cargo is not declared as such, or if one is declared but is stowed incorrectly, there is a chance that the cargo will self-heat. Early signs of self-heating of cargo typically occur unseen within a container and a first external evidence of such an event is when  
20 combustion of the cargo has begun. The combustion of the cargo typically leads to uncontrolled fire within the container, resulting in the destruction of the cargo and additional damage to the surroundings of the burning container. Such fire is particularly destructive when it occurs at sea as the container concerned cannot be moved and access to it is restricted. Fires seated in individual containers have, on more than one  
25 occasion, led to the total loss of the vessel that was carrying them.

30 Carriers have tried various methods to control the mis-declaration of goods and to better enforce 'best practice' for the stowage of such goods (e.g. including banning some goods from containerised carriage) to control the risk of container fires. However, these have had limited success. It is fair to say that container fires are an endemic problem to the sealable container freight industry with an estimated average of a container fire once every two weeks.

For ignition to occur, a fire requires fuel (in this case the cargo itself), heat and oxygen. With an oxygen content of 21% by volume, atmospheric air provides enough oxygen to satisfy the requirement for ignition. However, at an oxygen content of 16% and below, this oxygen requirement for ignition is not met and ignition rarely occurs. The actual  
5 percentage of oxygen at which ignition no longer occurs is specific to each type of fuel and is referred to as the Limiting Oxygen Concentration. As an example, the Limiting Oxygen Concentration for paper is 14.1%. One way of preventing container fires and controlling this inherent risk is therefore to prevent a cargo's progression from self-heating to combustion by controlling the atmosphere around the cargo to less than the  
10 Limiting Oxygen Concentration for that cargo. However, for such a solution to be effective, it will need to be able to integrate seamlessly into an existing operational framework of the multimodal container freight industry.

It is therefore desirable to provide a module and method for providing an inert environment in a sealable container and a sealable container which addresses the  
15 problems of the prior art and/or provides a useful alternative.

Furthermore, other desirable features and characteristics will become apparent from the subsequent detailed description and the appended claims, taken in conjunction with the accompanying drawings and this background of the disclosure.

### Summary

20 Aspects of the present application relate to a module and method for providing an inert environment in a sealable container and a sealable container.

In accordance with a first aspect, there is provided a module for providing an inert environment in a sealable container, the module comprising: an inlet adapted to fluidly connect to the sealable container for withdrawing atmospheric air from the sealable  
25 container, an outlet adapted to fluidly connect to the sealable container for providing inert gas to the sealable container, a pump configured to withdraw the atmospheric air from the sealable container via the inlet, and an inert gas generator configured to generate the inert gas using the withdrawn atmospheric air and to provide the inert gas to the sealable container via the outlet for providing the inert environment in the  
30 sealable container.

Thus, the described embodiment provides a module for providing an inert environment in a sealable container. Particularly, by having a pump configured to withdraw atmospheric air from the sealable container and an inert gas generator configured to generate the inert gas using the withdrawn atmospheric air and to provide the inert gas to the sealable container, the module advantageously achieves a circulation of air between the module and the sealable container for providing the inert environment in the sealable container (e.g. a low oxygen concentration environment below the Limiting Oxygen Concentration of the cargo). The inert environment is advantageous in rendering the container atmosphere non-flammable, thereby preventing fire ignitions in the sealable container. Further, by including the inert gas generator which is configured to generate an inert gas, the module does not require external sources of inert gas for providing the inert environment. This also means that the inert environment can be provided and maintained throughout transportation, given that the inert gas can be provided by the inert gas generator in a continuous manner if required. In addition, the module can be retrofitted to existing or conventional containers without the need to amend current container shipping practices or create additional infrastructure. This provides ease of implementing the module and minimises upstart costs.

The module may be integrated with the sealable container to form part of the sealable container.

The module may occupy 5% to 15% of a total volume of the sealable container. The module therefore does not take up much cargo space in the sealable container.

The module may comprise a filtration unit configured to filter the atmospheric air withdrawn from the sealable container. The filtration unit may comprise at least one removable particulate filter. In this way, the withdrawn atmospheric air is filtered to remove any particles which may impede an efficiency of the inert gas generator in generating the inert gas. Further, the removable particulate filter provides a mechanism for verifying a content of the sealable container. For example, the removable particulate filter of the filtration unit can be removed and examined, e.g. using an ion scanner or similar technology, to check for trace amounts of explosives, narcotics or other prohibitive substances. This process avoids the need to carry out a costly and time-consuming manual search of any suspect container.

The module may comprise an air dryer configured to dehumidify the atmospheric air withdrawn from the sealable container. The air dryer aids in lowering a humidity within the sealable container. Lower humidity may also aid in an operating efficiency of the inert gas generator.

- 5     The module may comprise a first humidity sensor at an input of the air dryer adapted to detect a humidity of the atmospheric air in the sealable container.

The module may comprise a second humidity sensor at an output of the air dryer adapted to detect a humidity of the dehumidified atmospheric air for monitoring an operational efficiency of the air dryer.

- 10    The module may comprise a vent for venting oxygen-rich by-product produced by the inert gas generator, and a first oxygen sensor at the vent adapted to detect an oxygen concentration of the vented oxygen-rich by-product for monitoring an operational efficiency of the inert gas generator.

- 15    The module may comprise a pressure sensor at an output of the pump adapted to detect an output pressure of the pump for monitoring an operational efficiency of the pump.

- 20    The module may comprise a temperature sensor located at the inlet of the module for detecting an ambient temperature in the sealable container. The temperature sensor enables monitoring of the ambient temperature in the sealable container. Any elevation of the ambient temperature may indicate an initiation of self-heating of the cargo with the sealable container, and early intervention to prevent any fire can be readily implemented.

- 25    In accordance with a second aspect, there is provided a sealable container, the sealable container comprising: any aforementioned module, an inlet opening adapted to connect to the outlet of the module; and an outlet opening adapted to connect to the inlet of the module.

- 30    The sealable container may comprise: an inlet valve connected to the inlet; and an outlet valve connected to the outlet, wherein the inlet valve is adapted to control a gas flow from the sealable container to the module and the outlet valve is adapted to control a gas flow from the module to the sealable container.

The sealable container may comprise a second oxygen sensor at the inlet of the module adapted to detect an oxygen concentration of the atmospheric air withdrawn from the sealable container.

5 The sealable container may comprise a module controller adapted to control an opening and closing of each of the inlet valve and the outlet valve in relation to the detected oxygen concentration of the second oxygen sensor for achieving a predetermined oxygen concentration in the sealable container.

10 The module controller may be configured to open the inlet valve and the outlet valve if the detected oxygen concentration is above the predetermined oxygen concentration and to close the inlet valve and the outlet valve if the detected oxygen concentration is equal to or below the predetermined oxygen concentration.

15 The module controller may be adapted to switch on and off the pump and the inert gas generator, and the module controller may be adapted to switch on the pump and the inert gas generator if the detected oxygen concentration is above the predetermined oxygen concentration and to switch off the pump and the inert gas generator if the detected oxygen concentration is equal to or below the predetermined oxygen concentration. This works to conserve power for the module by switching off the pump and the inert gas generator once the predetermined oxygen concentration in the sealable container is reached.

20 The sealable container may comprise a bypass duct adapted to isolate the inert gas generator. The module controller may be adapted to open the inlet valve and the outlet valve and to activate the bypass duct to isolate the inert gas generator if the detected oxygen concentration is equal to or below the predetermined oxygen concentration. The bypass duct allows isolation of the inert gas generator from the circulating atmosphere, particularly if the detected oxygen concentration is equal to or below the predetermined oxygen concentration. This enables the module to be used,  
25 independently, for the filtering and/or dehumidifying of air in the sealable container even if the predetermined oxygen concentration in the sealable container is reached.

30 The sealable container may comprise an equalising vent adapted to equalise a pressure in the sealable container to a predetermined pressure.

The sealable container may comprise a power source configured to provide power to the module. The power source may include a portable battery or an external power supply.

5 The sealable container may comprise at least one solar cell externally attached to at least a wall of the sealable container, the at least one solar cell being electrically connected to the module for providing power to the module. The at least one solar cell provides another renewable source of power to the module, if necessary.

10 The sealable container may comprise a power system controller configured to determine a power requirement of the module using an output of the power source, an output of the at least one solar cell, a power consumption of the module for achieving the predetermined oxygen concentration in the sealable container, and the detected oxygen concentration by the second oxygen sensor. The determined power requirement of the module may be used to optimise the provision of power to the module, and may be customised based on a requirement of the transportation process  
15 of the sealable container.

The inlet opening may be placed at one end of the sealable container and the outlet opening may be placed at an opposite end of the sealable container. This maximises a distance between the inlet opening and the outlet opening in the sealable container, thereby improving a circulation of air within the sealable container and ensuring that the  
20 inert gas provided by the inert gas generator is effectively replacing the atmospheric air in the sealable container.

The sealable container may comprise at least a third oxygen sensor placed in the sealable container adapted to detect an oxygen concentration of the atmospheric air within the sealable container.

25 The sealable container may include a portable container.

The sealable container may comprise a transmitter configured to transmit data from the sealable container to a network for real-time monitoring of an atmospheric condition of the sealable container. The transmitter may be configured to transmit data in relation to information gathered on an operation of the pump and the inert gas generator of the  
30 module. This allows real-time remote monitoring of the conditions of the module and the sealable container and allows for intervention if necessary.

In accordance with a third aspect, there is provided a method for providing an inert environment in a sealable container, the method comprising: (i) withdrawing atmospheric air from the sealable container via an outlet opening of the sealable container; (ii) generating inert gas using the withdrawn atmospheric air; and (iii) providing the inert gas to the sealable container via an inlet opening of the sealable container, wherein the steps (i), (ii) and (iii) are performed in a continuous manner until a predetermined oxygen concentration in the sealable container is achieved for providing the inert environment in the sealable container.

The method may comprise compressing the withdrawn atmospheric air.

10 The method may comprise filtering the withdrawn atmospheric air.

The method may comprise dehumidifying the withdrawn atmospheric air.

The method may comprise providing fumigants in the sealable container.

The method may comprise: ceasing performance of the steps (i), (ii) and (iii) once the predetermined oxygen concentration in the sealable container is achieved; monitoring an oxygen concentration in the sealable container; and restarting the steps (i), (ii) and (iii) if the oxygen concentration in the sealable container rises above the predetermined oxygen concentration.

The method may comprise monitoring an ambient temperature in the sealable container.

20 Embodiments therefore provide a module and method for providing an inert environment in a sealable container, and a sealable container. Particularly, by withdrawing atmospheric air from the sealable container, generating inert gas using the withdrawn atmospheric air and providing the inert gas back to the sealable container, a circulation of air between the module and the sealable container for providing the inert environment in the sealable container (e.g. a low oxygen concentration environment below the Limiting Oxygen Concentration of the cargo) is achieved. The inert environment is advantageous in rendering the container atmosphere non-flammable, thereby preventing fire ignitions in the sealable container. Further, by including the inert gas generator which is configured to generate an inert gas, the module does not require external sources of inert gas for providing the inert environment. This also

means that the inert environment can be provided and maintained throughout transportation, given that the inert gas can be provided by the inert gas generator in a continuous manner if required. Other advantages associated with other features of the module, the method and the sealable container are discussed above.

5    Brief description of the drawings

Embodiments will now be described, by way of example only, with reference to the following drawings, in which:

Figure 1 shows a schematic diagram of a module for providing an inert environment in a sealable container and the sealable container in accordance with an embodiment;

- 10   Figure 2 shows a schematic diagram of the module and the sealable container of Figure 1, inclusive of their components, in accordance with an embodiment;

Figure 3 is a flowchart showing steps of a method for providing an inert environment in a sealable container in accordance with an embodiment;

- 15   Figure 4 is a flowchart showing steps of a method for operating the module of Figure 1 to maintain a predetermined oxygen concentration in a sealable container in accordance with an embodiment;

Figure 5 shows a schematic diagram illustrating a sealable container comprising the module of Figure 1 in accordance with an embodiment, where the module is integrated with the sealable container to form part of the sealable container; and

- 20   Figure 6 shows a schematic diagram of an operation of the sealable container of Figure 5 in accordance with an embodiment.

Detailed description

An exemplary embodiment relates to a module and method for providing an inert environment in a sealable container and a sealable container.

- 25   Figure 1 shows a schematic diagram 100 of a module 102 for providing an inert environment in a sealable container 104 and the sealable container 104 in accordance with an embodiment. The sealable container 104 includes any container where its enclosure can be reasonably sealed to prevent or minimise leakage of the atmosphere

within its enclosure to an external surrounding. The module 102 is fluidly connected to the sealable container 104 and is configured to withdraw atmospheric air from the sealable container 104 in a step 106, and to provide inert gas to the sealable container 104 in a step 108. This provides a circulation of air between the module 102 and the sealable container 104, where the atmospheric air from the sealable container 104 is processed to generate inert gas and the inert gas is circulated back to the sealable container 104. The inert environment provided in the sealable container 104 is advantageous in preventing fire ignitions in the sealable container 104.

Figure 2 shows a schematic diagram of the module 102 and the sealable container 104 of Figure 1, inclusive of their components, in accordance with an exemplary embodiment. The optional features or components of the module 102 and the sealable container 104 are shown in dotted boxes. The arrows in Figure 2 denote a direction of air flow. A skilled person will therefore appreciate that the different components of the module 102 are fluidly connected so that the withdrawn air from the sealable container 104 can flow from one component to another in the module 102 as will be described below.

In the present embodiment, the module 102 comprises an inlet 202 adapted to be fluidly connected to the sealable container 104 for withdrawing atmospheric air from the sealable container 104, an outlet 204 adapted to be fluidly connected to the sealable container 104 for providing inert gas to the sealable container 104, a pump 206 configured to withdraw the atmospheric air from the sealable container 104 via the inlet 202, and an inert gas generator 208 configured to generate the inert gas using the withdrawn atmospheric air from the pump 206 and to provide the inert gas to the sealable container 104 via the outlet 204 for providing the inert environment in the sealable container 104. As shown in Figure 2, the module 102 is a separate entity which can be retrofitted to the sealable container 104. In another embodiment, for example as discussed in relation to Figures 5 and 6 below, the module 102 is integrated with the sealable container 104 and form part of the sealable container 104.

In the present embodiment (not shown in Figure 2), an inlet valve and an outlet valve are also connected to the inlet 202 and the outlet 204 of the module 102, respectively. The inlet valve is adapted to control a gas flow from the sealable container 104 to the module 102, while the outlet valve is adapted to control a gas flow from the module 102

to the sealable container 104. These valves provide control in the air circulation between the module 102 and the sealable container 104.

The pump 206 as defined in the present disclosure is intended to include a compressor or any equivalent device which is capable of withdrawing air. In an embodiment where  
5 the pump 206 includes a compressor, besides withdrawing atmospheric air from the sealable container 104, the pump 206 (or the compressor) is also capable of compressing the withdrawn atmospheric air into compressed air before delivering the compressed air to the inert gas generator 208. This is particularly useful for  
10 embodiments where the inert gas generator utilises a pressure swing adsorption or a membrane method for gas separation. In an embodiment where a pump which delivers the withdrawn atmospheric air to the inert gas generator 208 at atmospheric pressure is used, a temperature swing adsorption method for gas separation can be employed. In the present embodiment, the pump 206 includes a compressor.

The inert gas generator 208 may include a nitrogen generator or a carbon dioxide  
15 generator for providing nitrogen gas or carbon dioxide gas, respectively. The nitrogen gas or the carbon dioxide gas can then be used to provide an inert environment in the sealable container 104.

Besides the inlet 202, the outlet 204, the pump 206 and the inert gas generator 208,  
20 the module 102 may optionally include a filtration unit 210, an air dryer 212, a vent 214, a power source 216, a transmitter/receiver 218 and a bypass duct 220.

The filtration unit 210 is configured to filter the atmospheric air withdrawn from the sealable container 104, and may comprise at least one removable particulate filter. The air dryer 212 is configured to dehumidify or dry the atmospheric air withdrawn from the sealable container 104. The air dryer 212 may include a drain for draining water  
25 extracted from the atmospheric air. The vent 214 is configured to vent oxygen-rich by-product 222 produced by the inert gas generator 208 to an external atmosphere. As shown in Figure 2, the vent is fluidly connected to the inert gas generator 208 for exhausting the oxygen-rich by-product 222 from the inert gas generator 208. In another embodiment, the oxygen-rich by-product 222 may be exhausted by the inert gas  
30 generator 208 external of the module 102 directly. The vent 214 may include a non-return valve for preventing the vented oxygen-rich by-product 222 from re-entering the module 102 or the inert gas generator 108. In the present embodiment, the power

source 216 is provided as part of the module 102 configured to provide power to the module 102. The power source 216 may include a battery, a photovoltaic cell or a solar cell, or it may be adapted to be connected to an external power source. The module 102 of the present embodiment also includes the transmitter/receiver 218. The transmitter/receiver includes a transmitter and a receiver, and these may be formed as separate entities or as an integrated entity. The transmitter is configured to transmit data to a network for real-time monitoring of an atmospheric condition of the sealable container 104 and/or to transmit data in relation to information gathered on an operation of the pump 206, the inert gas generator 208 and/or other components of the module 102 (e.g. the filtration unit 210 and/or the air dryer 212) for monitoring an operation efficiency of the module 102. The receiver is configured to receive data in relation to an operation of the module 102, for example in setting a predetermined oxygen concentration or a predetermined pressure in the sealable container 104. Further, the module 102 in the present embodiment includes a bypass duct 220 (shown as a dotted arrow). The bypass duct 220 is adapted to isolate the inert gas generator 208. Particularly, if the detected oxygen concentration in the withdrawn air is equal to or below a predetermined oxygen concentration, the bypass duct 220 can be activated to isolate the inert gas generator 208 from the circulation. This enables the module 102 to be used, independently, for the filtering and/or dehumidifying of air in the sealable container 104 even if the predetermined oxygen concentration in the sealable container 104 has been reached.

As shown in Figure 2, the sealable container 104 includes an outlet opening 224, an inlet opening 226 and an equalising vent 228. The outlet opening 224 is adapted to connect to the inlet 202 of the module 102 for withdrawing atmospheric air from the sealable container 104 by the module 102, while the inlet opening 226 is adapted to connect to the outlet 204 of the module 102 for receiving inert gas provided by the module 102. The equalising vent 228 is adapted to equalise a pressure in the sealable container 104 to a predetermined pressure. To do this, the equalising vent 228 may allow air intake 230 from external atmosphere so as to balance a pressure within the sealable container 104, as the removal of oxygen-rich by-product 222 from the atmospheric air lowers the pressure within the sealable container 104. In the present embodiment, the sealable container 104 also comprise at least one solar cell externally attached to at least one wall of the sealable container 104. The at least one solar cell is

adapted to be electrically connected to the module 102, for example to the power source 216, for providing power to the module 102.

In addition to the components of the module 102 and the sealable container 104 as described above, a system can also be provided to control and monitor various parameters associated with an operation of the module 102 and conditions of the sealable container 104. The system is not shown in Figure 2 for brevity and clarity. The system may be included in the module 102 and form part of the module 102, or it may be included in the sealable container 104 and form part of the sealable container 104 for an embodiment where the module 102 is integrated with the sealable container 104.

10 In the present embodiment, the system includes a plurality of sensors for sensing a temperature, a humidity, a pressure and an oxygen concentration, and these sensors are placed at various locations of the module 102 and/or the sealable container 104.

For example, in the present embodiment, a first humidity sensor of the module 102 can be placed at an input of the air dryer 212 adapted to detect a humidity of the atmospheric air in the sealable container 104, while a second humidity sensor can be placed at an output of the air dryer 212 adapted to detect a humidity of the dehumidified atmospheric air for monitoring an operational efficiency of the air dryer 212. A third humidity sensor can also be placed within an enclosure of the sealable container 104 for providing an additional humidity reading within the sealable container 104 and can function as a back-up to the first humidity sensor.

In relation to sensing of an oxygen concentration, in the present embodiment, a first oxygen sensor is placed at the vent 214 for detecting an oxygen concentration of the vented oxygen-rich by-product 222 for monitoring an operational efficiency of the inert gas generator 208, and a second oxygen sensor is placed at the inlet 202 of the module 102 for detecting an oxygen concentration of the atmospheric air withdrawn from the sealable container 104. A third oxygen sensor can be placed within an enclosure of the sealable container 104 for detecting an oxygen concentration of the atmospheric air within the sealable container 104. This third oxygen sensor can be placed at an opposite end to the second oxygen sensor (e.g. near or around the inlet opening 226 of the sealable container 104). The readings from the second oxygen sensor and the third oxygen sensor may be compared to determine an average oxygen concentration of the atmospheric air within the enclosure of the sealable container 104.

In this exemplary embodiment, a first pressure sensor is also placed at an output of the pump 206 for detecting an output pressure of the pump for monitoring an operational efficiency of the pump 206. A second pressure sensor can also be placed at an input of the pump 206 for detecting an input pressure of the pump 206. The readings of the second pressure sensor can be corroborated with the readings of the first pressure sensor for monitoring an efficiency of the pump 206. A third sensor can also be placed within the enclosure of the sealable container 104 for monitoring a pressure within the sealable container 104.

Further, a first temperature sensor can be placed at the inlet 202 of the module 102 and a second temperature sensor can be placed within the enclosure of the sealable container 104 for detecting an ambient temperature in the sealable container 104. These temperature sensors provide temperature readings at different locations of the module 102 and the sealable container 104, and can be corroborated to enable real-time monitoring of the ambient temperature in the sealable container. Any elevation of the ambient temperature may indicate an initiation of self-heating of the cargo within the sealable container 104, and early intervention to prevent any fire can be readily implemented.

Besides the various sensors as described above, the system of the present embodiment also includes a module controller for controlling circulation of air in the module 102 and the sealable container 104, and a power system controller for determining a power requirement of the module 102 and optimising a power output to the module 102.

In the present embodiment, the module controller is configured to control an opening and closing of the inlet valve and the outlet valve in relation to the detected oxygen concentration of the second oxygen sensor and/or the third oxygen sensor. If the detected oxygen concentration is above the predetermined oxygen concentration, the module controller is configured to open the inlet valve and the outlet valve so that the module 102 and the sealable container 104 are fluidly connected and inert gas can be provided from the module 102 to the sealable container 104 for lowering the oxygen concentration in the sealable container 104 to the predetermined oxygen concentration. On the other hand, if the detected oxygen concentration is equal to or below the predetermined oxygen concentration, the module controller is configured to close the

inlet valve and the outlet valve so that the sealable container 104 is isolated from the module 102. In the present embodiment, the module controller is also adapted to switch on and off the pump 206 and/or the inert gas generator 208, independently. For example, the module controller is adapted to switch off at least the pump 206 and the inert gas generator 208 if the detected oxygen concentration is equal to or below the predetermined oxygen concentration, so as to conserve power for the module 102 once the predetermined oxygen concentration in the sealable container is reached. In a practical system, the oxygen concentration in the sealable container 104 may rise over time due to leakages. Therefore, the module controller is also adapted to open the inlet valve and the outlet valve, and to switch on the pump 206 and the inert gas generator 208, if the detected oxygen concentration is above the predetermined oxygen concentration. The inert gas can then be provided to the sealable container 104 for lowering the oxygen concentration in the sealable container 104 to the predetermined oxygen concentration.

Besides the above operation, the module controller can also be adapted to open the inlet valve and the outlet valve, and to activate the bypass duct 220 to isolate the inert gas generator 208, if the detected oxygen concentration is equal to or below the predetermined oxygen concentration. In this case, the bypass duct 220 allows isolation of the inert gas generator 208 from the circulating atmosphere, but enables the module 102 to be used, independently, for the filtering and/or dehumidifying of air in the sealable container 104 even if the predetermined oxygen concentration in the sealable container 104 is reached. In this case, the module controller is adapted to independently switch off the inert gas generator 208 while maintaining an operation of the pump 206 to continue the circulation of air between the module 102 and the sealable container 104.

In the present embodiment, the power system controller is configured to determine a power requirement of the module 102 using (a) an output of the power source 216, (b) an output of the at least one solar cell, (c) a power consumption of the module 102 for achieving the predetermined oxygen concentration in the sealable container, and (d) the detected oxygen concentration by the second oxygen sensor and/or the third oxygen sensor. The determined power requirement of the module 102 can be used to optimise the provision of power to the module 102. This enables the module 102 and/or the sealable container 104 to be customised to ensure that sufficient power is provided

to the module 102, taking into consideration of the power requirement of the module 102 and a transportation process of the sealable container 104.

Figure 3 is a flowchart showing steps of a method 300 for providing an inert environment in the sealable container 104 in accordance with an embodiment. In the present embodiment, the method 300 uses the module 102 as described in relation to Figure 2 above. The optional steps of the method 300 are shown in dotted boxes.

In a step 302, the module 102 is configured to withdraw atmospheric air from the sealable container 104 via the outlet opening 224 of the sealable container 104.

In a step 304, the module 102 is configured to filter the withdrawn atmospheric air from the sealable container 104 using the filtration unit 210.

In a step 306, the module 102 is configured to dehumidify or dry the filtered air received from the filtration unit 210 using the air dryer 212. In another embodiment, the step 304 may not be performed and the module 102 is configured to dehumidify the withdrawn atmospheric air from the sealable container 104.

In a step 308, the module 102 is configured to compress the dehumidified air formed by the air dryer 212. In the present embodiment, the pump 206 includes a compressor which is capable of compressing the dehumidified and filtered air to form compressed air. As discussed above, in an embodiment where a temperature swing adsorption method is used, a pump may deliver the withdrawn atmospheric air to the inert gas generator 208 at atmospheric pressure and so the step 308 may not be performed.

In a step 310, the module 102 is configured to generate inert gas using the inert gas generator 208 using the compressed air formed at the step 308.

In a step 312, the module 102 is configured to provide the inert gas formed at the step 310 to the sealable container 104 via the inlet opening 226 of the sealable container 104. In the present embodiment, the aforementioned steps 302 to 312 are performed in a continuous manner until a predetermined oxygen concentration in the sealable container 104 is achieved for providing the inert environment in the sealable container 104. The predetermined oxygen concentration can vary depending on a requirement of the sealable container 104 and can be specific to the goods intended to be transported using the sealable container 104. For example, the predetermined oxygen

concentration can be set to the Limiting Oxygen Concentration associated with the goods to be transported by the sealable container. In an embodiment, a suitable range of the predetermined oxygen concentration is from 10% to 15%.

Figure 4 is a flowchart showing steps of a method 400 for operating the module 102 of Figure 1 to maintain a predetermined oxygen concentration in the sealable container 104 in accordance with an embodiment. This relates to a use of the system comprising the module controller and at least the second oxygen sensor and/or the third oxygen sensor as afore described.

In a step 402, the module 102 is configured to determine if the predetermined oxygen concentration in the sealable container 104 is achieved. As described above, the predetermined oxygen concentration in the sealable container 104 is detected or measured using the second oxygen sensor placed at the inlet of the module 102 or the third oxygen sensor placed within the enclosure of the sealable container 104. The determining step in the step 402 can be performed periodically, for example, at 5-minute intervals, at 10-minute intervals, at 20-minute intervals or any time intervals which is deemed suitable. A suitable time interval for performing the step 402 is one which is correlative with a total time it will take for the sealable container 104 to reach the predetermined oxygen concentration, and may vary depending on a size of the sealable container 104, a predetermined oxygen concentration required, and a circulation rate associated with a provision of the inert gas for replacing the atmospheric air in the sealable container 104.

If it is determined that the predetermined oxygen concentration in the sealable container 104 is achieved, then in a step 404, the module 102 is configured to cease operation of the steps 302 to 312 of Figure 3. In the present embodiment, this means that the module 102, via the module controller, is configured to close the inlet valve and the outlet valve so that the sealable container 104 is isolated from the module 102. In this way, the steps 302-312 will not be performed. In the present embodiment, the module controller is also adapted to switch off at least the pump 206 and the inert gas generator 208 once the inlet valve and the outlet valve are closed, so as to conserve power for the module 102, although this should be understood to be optional.

In a step 406, the module 102 is configured to monitor an oxygen concentration in the sealable container 104. This may be achieved using the second oxygen sensor and/or

the third oxygen sensor. Similar to the step 402, the oxygen concentration in the sealable container 104 can be monitored in suitable intervals.

In a step 408, if the oxygen concentration in the sealable container 104 is determined to have risen above the predetermined oxygen concentration, the module 102, via the module controller, is configured to open the inlet valve and the outlet valve so that the module 102 and the sealable container 104 are again fluidly connected. If the pump 206 and the inert gas generator 208 were switched off at the step 404, the module 102, via the module controller, is configured to switch on the pump 206 and the inert gas generator 208 so that circulation of air between the module 102 and the sealable container 104 is resumed and inert gas can be provided to the sealable container 104 until the predetermined oxygen concentration in the sealable container 104 is reached.

Therefore, in the step 408, the inlet valve and the outlet valve are opened, and the pump 206 and the inert generator 208 are in operation so that the module 102 performs the steps 302 to 312. This leads back to the step 402 where the module 102 is configured to determine if the predetermined oxygen concentration in the sealable container 104 is achieved, and if the predetermined oxygen concentration in the sealable container 104 is achieved, then the steps 404 to 408 as previously described ensue.

If it is determined at the step 402 that the predetermined oxygen concentration in the sealable container 104 is not achieved, then the module 102 is configured to continue with the steps 302 to 312 in the step 410. This leads back to the step 402 again until it is determined that the predetermined oxygen concentration in the sealable container 104 is achieved, before the steps 404 to 408 as previously described are subsequently performed.

Besides the above operation as described, once the predetermined oxygen concentration in the sealable container 104 is achieved, the module controller can also be adapted to activate the bypass duct 220 to isolate the inert gas generator 208 while keeping the inlet valve and the outlet valve open. In this case, the module 102 can be used, independently, for filtering and/or dehumidifying of air in the sealable container 104 even if the predetermined oxygen concentration in the sealable container 104 is reached. Further, the module controller can be configured to independently switch off the inert gas generator 208 while maintaining an operation of the pump 206 at this time

so that the circulation of air between the module 102 and the sealable container 104 continue. The bypass duct 220 can be activated manually (either on-site or remotely) or it can be programmed to be activated automatically using the module controller, for example to continue with filtering and/or dehumidifying the air in the sealable container 104 even if the predetermined oxygen concentration in the sealable container 104 is reached. The skilled person would appreciate that other bypass duct(s) to isolate the filtration unit 210 and/or the air dryer 212 can also be installed so that functions of the filtration unit 210 and the air dryer 212 can be isolated and performed independently.

In an embodiment where the system does not include the second and/or the third oxygen sensor, the method 400 is not performed and the method 300 is performed in a continuous manner to provide inert gas to the sealable container 104. In another embodiment, the method 300 ceases once the predetermined oxygen concentration is reached without the performance of the method 400.

#### An exemplary sealable container

Figure 5 shows a schematic diagram illustrating a sealable container 500 comprising the module 102 of Figure 1 in accordance with an embodiment, where the module 102 is integrated with the sealable container 500 to form part of the sealable container 500.

In this exemplary embodiment, the sealable container 500 includes a dry container having a conventional twenty feet or forty feet steel floor with enhanced door seals, no external vents and an airtight bulkhead 502 located parallel to an end-wall 504. The bulkhead 502 divides the container 500 into two spaces, an airtight enclosure forming a cargo space 506 and a machinery space 508 for housing the module 102 which is vented to an external atmosphere. The machinery space 508 occupies approximately 10% of the entire container volume in the present embodiment, but this can range from 5% to 15% of a total volume of a container in another embodiment. In the present embodiment, the airtight bulkhead 502 has three openings through it, an outlet opening 510 leading to the module 102 within the machinery space 508 via an input duct, an inlet opening 512 leading from the module 102 to the cargo space 506 via an output duct, and an equalising vent 514. In the present embodiment, the input duct is flushed to the airtight bulkhead 502 at floor level whilst the output duct extends the length of the cargo space 506 at ceiling height to maximise a distance between the outlet opening

510 and the inlet opening 512. It would however be appreciated that other configurations of the outlet opening 510 and the inlet opening 512 are possible.

Also shown in Figure 5 is the process machinery of the module 102. This includes a filtration unit 516, an air dryer 518, a compressor 520, and a nitrogen generator 522. In the present embodiment, the filtration unit 516 includes at least one removable particulate filter and is configured to filter the atmospheric air withdrawn from the cargo space 506. The air dryer 518 is configured to dehumidify or dry the withdrawn air. The compressor 520 is configured to compress the air for providing compressed air to the nitrogen generator 522. In the present embodiment, the nitrogen generator 522 uses a membrane separation method and therefore requires use of the compressed air for generating nitrogen as an inert gas. Figure 5 also shows a vent 524 comprising a non-return valve for exhausting oxygen-rich stream from the nitrogen generator 522 to an external atmosphere, and a power source 526 for powering the module and/or the sealable container 500. In the present embodiment, the power source 526 includes a battery.

#### Operation of the sealable container

Figure 6 shows a schematic diagram 600 of an operation of the sealable container 500 of Figure 5 in accordance with an embodiment. Please note that the diagram 600 is not drawn to scale and the machinery space 508 has been enlarged for clarity. Similar features of the sealable container 500 have been labelled with same reference numbers as Figure 5.

Air is drawn through the outlet opening 510, via an inlet valve (not shown), to the filtration unit 516 by a negative pressure created at an input side of the compressor 520. The air withdrawn from the cargo space 506 is filtered using the filtration unit 516, and output to the air dryer 518 for drying. The water content 601 extracted from the air can be exhausted as shown in Figure 6 and this exhausted water may be recycled or used for other applications by the transport carrier. Once dehumidified, the clean, dry air from the output side of the air dryer 518 passes into the compressor 520 where it is compressed and passed on to the nitrogen generator 522. In the present embodiment, membrane separation is used which requires compressed air. In another embodiment, where a temperature swing adsorption method is used, a pump which delivers the withdrawn atmospheric air to an inert gas generator 208 at atmospheric pressure can

be used in place of the compressor 520 as discussed above. For the present case, the nitrogen generator 522 acts by taking a pressurised stream of air and separating it into a nitrogen-rich stream and an oxygen-rich stream. Here, 'rich' is a relative term defined as having a greater percentage by volume of a particular gas as compared to that of the input stream. For example, the nitrogen-rich stream produced by the nitrogen generator 522 means that this nitrogen-rich stream has a higher percentage by volume of nitrogen as compared to the air withdrawn from the cargo space 506 of the sealable container 500.

The oxygen rich stream is vented to the external atmosphere via the vent 524 and the nitrogen rich stream is returned to the cargo space 506 via an outlet valve and the output duct through the inlet opening 512. In the present embodiment, the volume of oxygen-rich stream vented to atmosphere by the system is replaced via the equalising vent 514 at the airtight bulkhead 502. The equalising vent 514 may also be placed at other sides of the cargo space 506 as long as the equalising vent 514 can be fluidly connected to the cargo space 506 (e.g. at a side wall of the sealable container 500). The equalising vent 514 includes a pressure-vacuum (PV) valve which responds to a decrease in pressure caused by the venting of oxygen rich air by admitting a similar volume of atmospheric air such that the pressure within the cargo space 506 is maintained. The equalising vent 514 may be controlled and adjusted by the module controller for maintaining a pressure in the sealable container 500 at a predetermined pressure (e.g. at atmospheric pressure or lower).

Through the operation of the module 102, an oxygen concentration of the air within the cargo space 506 is reduced and this reduction will continue as the air is continually cycled through the module 102. Once the oxygen concentration within the cargo space 506 has reached the predetermined oxygen concentration, a maintenance phase as described in relation to the method 400 may be performed to maintain the predetermined oxygen concentration in the sealable container 500.

### Sensors

In addition to the operation of the sealable container 500 as described, a system can also be provided to control and monitor various parameters associated with an operation of the module 102 and conditions of the cargo space 506 of the sealable container 500. The system includes a plurality of sensors for sensing a temperature, a

humidity, a pressure and an oxygen concentration, and these sensors are placed at various locations of the sealable container 500. The system of the present embodiment also includes a module controller for controlling circulation of air in the sealable container 500, and a power system controller for determining a power requirement of the process machinery and optimising a power output to the process machinery of the sealable container 500.

To control and monitor an oxygen concentration within the cargo space 506, an oxygen sensor 602 is placed at the outlet opening 510 or an inlet of the filtration unit 516 for detecting an oxygen concentration of the atmospheric air withdrawn from the cargo space 506. The module controller in the present embodiment is adapted to receive two inputs, a first input associated with a required oxygen concentration as determined by an operator or user of the sealable container 500, and a second input associated with an actual or real-time oxygen concentration as detected by the oxygen sensor 602. As discussed in relation to the methods 300 and 400 above, once the module 102 or the sealable container integrated with the module 102 is activated, the module controller is configured to open the inlet valve and the outlet valve, and to switch on the process machinery of the module 102. As described in relation to the method 300, the various components of the module operate to provide an inert gas (in this case, nitrogen) to the cargo space 506 of the sealable container 500. The process machinery continues to operate until the oxygen concentration detected by the oxygen sensor 602 is equal to the value of the first input provided by the operator. This is similar to that as described at the step 402 of the method 400 where the module controller is configured to determine if the predetermined oxygen concentration (i.e. the first input in this case) in the sealable container 500 has been reached. At this point, in the present embodiment, the module controller is configured to close the inlet valve and the outlet valve, and shut down the process machinery so that the steps 302 to 312 cease. The module controller continues to monitor the output of the oxygen sensor 602 and in the event that the oxygen concentration rises above the predetermined level, the module controller is configured to open the inlet valve and the outlet valve, and to reactivate the process machinery for performing the method 300 until the oxygen concentration within the cargo space 506 falls to the predetermined oxygen concentration again. This feedback loop to maintain the required oxygen concentration is continued until the module controller is deactivated by the operator.

Additional oxygen sensors can be deployed throughout the cargo space 506 if deemed necessary. In the present embodiment, a second oxygen sensor 604 is placed at the vent 524 for detecting an oxygen concentration of the vented oxygen-rich by-product for monitoring an operational efficiency of the nitrogen gas generator 522. Further, one  
5 or more oxygen sensors can be placed within the cargo space 506 for detecting an oxygen concentration of the atmospheric air within the sealable container 500. For example, a third oxygen sensor 606 can be placed at or around the inlet opening 512 for monitoring an overall efficiency of the process machinery.

The aforementioned oxygen sensors and other sensors which can be deployed within  
10 the sealable container 500 and/or the process machinery to monitor conditions of the sealable container 500 and an operating efficiency of the process machinery are listed in Table 1 below.

| Sensor Type | Location                        | Function                                           |
|-------------|---------------------------------|----------------------------------------------------|
| Humidity    | Air dryer input                 | Cargo space atmosphere monitoring                  |
| Humidity    | Air dryer output                | Air dryer efficiency monitoring                    |
| Pressure    | Compressor input                | Compressor efficiency monitoring                   |
| Pressure    | Compressor output               | Compressor efficiency monitoring                   |
| Oxygen      | Oxygen rich stream<br>vent duct | Nitrogen generator efficiency monitoring           |
| Oxygen      | Inlet opening                   | Overall process machinery efficiency               |
| Oxygen      | Outlet opening                  | Monitor oxygen concentration in the cargo<br>space |
| Temperature | Outlet opening                  | Monitor ambient temperature                        |
| Temperature | Within cargo space              | Monitor ambient temperature                        |

Table 1: Examples of sensors which can be used for monitoring operations of the module and conditions of the sealable container

In the present embodiment, a first humidity sensor 608 can be placed at an input of the air dryer 518 adapted to detect a humidity of the atmospheric air in the sealable container 500, while a second humidity sensor 610 at an output of the air dryer 518 adapted to detect a humidity of the dehumidified atmospheric air for monitoring an operational efficiency of the air dryer 518. One or more other humidity sensors can also be placed within the cargo space 506 for providing an additional humidity reading within the cargo space 506.

In relation to pressure sensing, a first pressure sensor 612 is placed at an output of the compressor 520 for detecting an output pressure of the compressor 520 for monitoring an operational efficiency of the compressor 520. A second pressure sensor 614 can also be placed at an input of the compressor 520 for detecting an input pressure of the compressor 520. The readings of the second pressure sensor 614 can be corroborated with the readings of the first pressure sensor 612 for monitoring an efficiency of the compressor 520. A third pressure sensor can also be placed within the cargo space 506 for monitoring a pressure within the sealable container 500. The ambient pressure within the cargo space can be controlled by the use of the PV valve located at the equalising vent 514 at the airtight bulkhead 502. In the present embodiment, the system is not able to produce a pressure above the ambient atmospheric pressure. Nonetheless, it can maintain a pressure in the cargo space 506 at the ambient pressure or below. Combined with suitably designed door seals, a cargo space pressure below the ambient pressure can be used to improve an airtight integrity of the cargo space 506.

As listed in Table 1, temperatures sensors can also be placed at the outlet opening 510 and within the cargo space 506 for detecting an ambient temperature in the sealable container 500. These temperature sensors provide temperature readings at different locations of the sealable container 500, and can be corroborated to enable real-time monitoring of the ambient temperature in the sealable container 500. Any elevation of the ambient temperature may indicate an initiation of self-heating of the cargo within the sealable container 500, and early intervention to prevent any fire can be readily implemented. In an embodiment, a module controller can be configured to trigger an alarm should the temperature exceed a pre-determined temperature value to provide early warning for a potential fire in the sealable container 500. The alarm may include

an identity and/or location of the sealable container 500 so that it can be located easily and quickly.

In the present embodiment, all of the sensor data generated from the aforementioned sensors is recorded and saved electronically within the module controller. This data  
5 can be accessed via a physical connection to the module controller with a suitable device (e.g. a USB drive) or via a wireless network (e.g. a WIFI or a satellite network). In an embodiment where the module controller is connected to a wireless network, the sealable container 500 comprises a transmitter and/or a receiver for transmitting data and/or receiving data from the wireless network. This network can be a local one, such  
10 as that onboard a vessel, or a wider satellite based one. This will allow real-time monitoring of the operations of the process machinery of the sealable container 500 and the conditions within the cargo space 506, for example to ensure that the oxygen concentration in the sealable container 500 is equal to or below the predetermined oxygen concentration and/or to detect early warning of potential cargo self-heating  
15 within the cargo space 506.

The predetermined or required oxygen concentration in the cargo space 506 and/or the activation of the processing machinery of the sealable container 500 can be done remotely or on-site at the sealable container 500. The data received by the module controller, for example an oxygen set level (i.e. the predetermined oxygen  
20 concentration), an actual oxygen concentration (i.e. the detected oxygen concentration in the cargo space 506) and a cargo space ambient temperature, can be displayed on a control panel of the module controller using an LCD. These parameters or data of the sensors can also be accessed and displayed remotely if the module controller is connected to a wireless network.

## 25 Power

The power requirements of the sealable container 500 are relatively low, especially after an oxygen concentration in the cargo space 506 has reached the predetermined level and only the maintenance cycle as described in the method 400 is required. If the cargo space 506 has a high degree of airtight integrity, there will be little or no oxygen  
30 concentration drift in the cargo space 506, and therefore little or no power will be required to maintain the predetermined oxygen concentration in the cargo space once the predetermined oxygen concentration is reached. Here, the oxygen concentration

drift is defined as a rate at which the oxygen concentration rises once the predetermined oxygen concentration in the cargo space 506 has been reached and the sealable container 500 has been sealed. This rate will depend on the airtight integrity of the cargo space and the nature of the cargo, type of packaging etc., and may be  
5 determined/estimated for individual sealable container.

In the present embodiment, besides the power source 526, the sealable container 500 can also be connected to an external electrical power source and/or to photovoltaic cells located on external walls (e.g. external roof and/or side walls) of the sealable container 500. The external electrical power source, the photovoltaic cells, and the  
10 power source 526 (e.g. a storage battery) of the module work together to provide power to the sealable container 500. For example, the external power source can be used to charge up the storage battery so that the storage battery can provide sufficient power when no external power is available. The photovoltaic cells provide renewable  
15 energy and can be used to supplement the power provided by the external power source and/or the storage battery. This hybrid model gives flexibility on how the sealable container 500 can be handled through the transport chain depending on the individual characteristics/requirements of each voyage. For example, some voyages may require the sealable container 500 to be shipped as if it was a standard refrigerated container with near continuous access to an external power, while other  
20 voyages may require the sealable container 500 to be a standard dry container with no external power source.

In the present embodiment, the power system controller monitors the external power input and the photovoltaic cell power input, the power consumption of the process machinery and the battery charge percentage. Using these parameters, along with the  
25 required oxygen concentration for the cargo space 506 and an estimated oxygen concentration drift, the power system controller is configured to calculate a power requirement of the sealable container 500 and optimise its provision. This enables the sealable container 500 to be customised to ensure that sufficient power is provided to the module, taking into consideration the power requirement of the module and a  
30 transportation process of the sealable container 500.

Similar to the sensor data above, data associated with power management can also be stored within the power system controller and be made available either on-site or

wirelessly as required. The power management data can also be displayed on the sealable container 500 via a liquid crystal display (LCD) panel of the power system controller.

#### Additional Functionality

- 5 Besides the functionalities as described above, an additional benefit of the circulation and filtering of the atmospheric air within the sealable container 500 is that the circulation and filtering of the atmosphere around the cargo provides a mechanism to verify the contents of the cargo in the sealable container 500. One or more of the filters in the filtration unit of the module can be replaceable (e.g. with the option of using a
- 10 new filter for every transit) and the machinery space 508 is an enclosed area that can be security sealed at a loading location. At any point in the transit of the sealable container 500, customs officers will be able to access the filters and, using an ion scanner or similar technology, check the cargo for trace amounts of explosives, narcotics or other prohibitive substances. This process would avoid the need to carry
- 15 out a costly and time-consuming manual search of any suspicious container.

The module controller of the sealable container 500 in the present embodiment can also be adapted to open the inlet valve and the outlet valve, and to activate a bypass duct (not shown) to isolate the nitrogen generator 522, if the detected oxygen concentration in the cargo space 506 is equal to or below the predetermined oxygen

20 concentration. In this case, the bypass duct allows isolation of the nitrogen generator 522 from the circulating atmosphere, but enables independent filtering and dehumidifying of air in the sealable container 500 even if the predetermined oxygen concentration in the sealable container 500 is reached. The degree by which the moisture content is reduced can be controlled using humidity sensors connected to the

25 module controller as previously described. In an embodiment, continuing circulation of air within the sealable container 500 with the nitrogen generator 522 bypassed also allow fumigants to be circulated throughout a volume of the sealable container 500 if required. In some cases, use of an inert atmosphere may negate the need to use fumigants or, where they can be safely used in conjunction with the nitrogen generator

30 522, reduce an amount of fumigant required.

Other alternative embodiments include: (1) the inert gas generator comprising a nitrogen generator or a carbon dioxide generator; (2) the inlet valve and/or the outlet

- valve comprising a solenoid valve; (3) the inert gas generator using a temperature swing adsorption or pressure swing adsorption method; (4) use of a pump which delivers the withdrawn atmospheric air to the inert gas generator 208 at atmospheric pressure, or a compressor, or both for withdrawing atmosphere air from an enclosure or cargo space of a sealable container; (5) a cargo space of a sealable container being not completely sealed and use of method 300 in a continuous manner for providing inert gas to the cargo space and maintaining an oxygen concentration in the cargo space at a predetermined oxygen concentration/level; (6) the predetermined oxygen concentration having a range or a band with a lower end point and a higher end point, for example 10% to 15% oxygen concentration; (7) a sealable container having an equalising vent that faces external to the sealable container; (8) a filtration unit and an air dryer in a different order as shown in Figures 5 or 6 so that withdrawn air from a cargo space passes through the air dryer to be dehumidified prior to passing through the filtration unit for filtering; (9) the module being secured with restricted access once the sealable container is sealed; (10) the module controller and/or the power system controller being controlled via a secured physical access or a secured wireless network to avoid any mishandling of the module and/or sealable container; (11) a filtration unit comprising one or more of: a HEPA filter, a fibreglass filter, a polyester and pleated filter; (12) the vent for venting oxygen-rich by-product may be part of or integrated with the inert gas generator; (13) a transmitter configured to transmit data to a network for real-time monitoring of an atmospheric condition of the sealable container and/or an operation of the module, and/or a receiver configured to receive data in relation to an operation of the module; and (14) a module which does not include an inlet valve and/or an outlet valve.
- Although only certain embodiments of the present invention have been described in detail, many variations are possible in accordance with the appended claims. For example, features described in relation to one embodiment may be incorporated into one or more other embodiments and vice versa.

Claims

1. A module for providing an inert environment in a sealable container, the module comprising:
  - an inlet adapted to fluidly connect to the sealable container for withdrawing
  - 5 atmospheric air from the sealable container;
  - an outlet adapted to fluidly connect to the sealable container for providing inert gas to the sealable container;
  - a pump configured to withdraw the atmospheric air from the sealable container via the inlet; and
  - 10 an inert gas generator configured to generate the inert gas using the withdrawn atmospheric air and to provide the inert gas to the sealable container via the outlet for providing the inert environment in the sealable container.
2. The module of claim 1, wherein the module is integrated with the sealable container
- 15 to form part of the sealable container.
3. The module of claim 2, wherein the module occupies 5% to 15% of a total volume of the sealable container.
- 20 4. The module of any preceding claim, further comprising a filtration unit configured to filter the atmospheric air withdrawn from the sealable container.
5. The module of claim 4, wherein the filtration unit comprises at least one removable particulate filter.
- 25 6. The module of any preceding claim, further comprising an air dryer configured to dehumidify the atmospheric air withdrawn from the sealable container.
7. The module of claim 6, further comprising a first humidity sensor at an input of the air
- 30 dryer adapted to detect a humidity of the atmospheric air in the sealable container.
8. The module of claim 6 or claim 7, further comprising a second humidity sensor at an output of the air dryer adapted to detect a humidity of the dehumidified atmospheric air for monitoring an operational efficiency of the air dryer.

9. The module of any preceding claim, further comprising:  
a vent for venting oxygen-rich by-product produced by the inert gas generator;  
and  
5 a first oxygen sensor at the vent adapted to detect an oxygen concentration of the vented oxygen-rich by-product for monitoring an operational efficiency of the inert gas generator.
10. The module of any preceding claim, further comprising a pressure sensor at an  
10 output of the pump adapted to detect an output pressure of the pump for monitoring an operational efficiency of the pump.
11. The module of any preceding claim, further comprising a temperature sensor  
located at the inlet of the module for detecting an ambient temperature in the sealable  
15 container.
12. A sealable container comprising:  
a module of any one of claims 1 to 11;  
an inlet opening adapted to connect to the outlet of the module; and  
20 an outlet opening adapted to connect to the inlet of the module.
13. The sealable container of claim 12, further comprising:  
an inlet valve connected to the inlet; and  
an outlet valve connected to the outlet,  
25 wherein the inlet valve is adapted to control a gas flow from the sealable container to the module and the outlet valve is adapted to control a gas flow from the module to the sealable container.
14. The sealable container of claim 13, further comprising a second oxygen sensor at  
30 the inlet of the module adapted to detect an oxygen concentration of the atmospheric air withdrawn from the sealable container.
15. The sealable container of claim 14, further comprising a module controller adapted to control an opening and closing of each of the inlet valve and the outlet valve in

relation to the detected oxygen concentration of the second oxygen sensor for achieving a predetermined oxygen concentration in the sealable container.

16. The sealable container of claim 15, wherein the module controller is configured to  
5 open the inlet valve and the outlet valve if the detected oxygen concentration is above the predetermined oxygen concentration and to close the inlet valve and the outlet valve if the detected oxygen concentration is equal to or below the predetermined oxygen concentration.
- 10 17. The sealable container of any one of claims 15 and 16, wherein the module controller is further adapted to switch on and off the pump and the inert gas generator, the module controller is adapted to switch on the pump and the inert gas generator if the detected oxygen concentration is above the predetermined oxygen concentration and to switch off the pump and the inert gas generator if the detected oxygen  
15 concentration is equal to or below the predetermined oxygen concentration.
18. The sealable container of claim 16, further comprising a bypass duct adapted to isolate the inert gas generator.
- 20 19. The sealable container of claim 18, wherein the module controller is adapted to open the inlet valve and the outlet valve and to activate the bypass duct to isolate the inert gas generator if the detected oxygen concentration is equal to or below the predetermined oxygen concentration.
- 25 20. The sealable container of any one of claims 12 to 19, further comprising an equalising vent adapted to equalise a pressure in the sealable container to a predetermined pressure.
21. The sealable container of any one of claims 15 to 20, further comprising a power  
30 source configured to provide power to the module.
22. The sealable container of claim 21, further comprising at least one solar cell externally attached to at least a wall of the sealable container, the at least one solar cell being electrically connected to the module for providing power to the module.

23. The sealable container of claim 22, further comprising a power system controller configured to determine a power requirement of the module using an output of the power source, an output of the at least one solar cell, a power consumption of the module for achieving the predetermined oxygen concentration in the sealable container, and the detected oxygen concentration by the second oxygen sensor.

24. The sealable container of any one of claims 12 to 23, wherein the inlet opening is placed at one end of the sealable container and the outlet opening is placed at an opposite end of the sealable container.

25. The sealable container of any one of claims 12 to 24, further comprising at least a third oxygen sensor placed in the sealable container adapted to detect an oxygen concentration of the atmospheric air within the sealable container.

26. The sealable container of any one of claims 12 to 25, wherein the sealable container includes a portable container.

27. The sealable container of any one of claims 12 to 26, further comprising a transmitter configured to transmit data from the sealable container to a network for real-time monitoring of an atmospheric condition of the sealable container.

28. The sealable container of claim 27, wherein the transmitter is further configured to transmit data in relation to information gathered on an operation of the pump and the inert gas generator of the module.

29. A method for providing an inert environment in a sealable container, the method comprising:

- (i) withdrawing atmospheric air from the sealable container via an outlet opening of the sealable container;
- (ii) generating inert gas using the withdrawn atmospheric air; and
- (iii) providing the inert gas to the sealable container via an inlet opening of the sealable container,

wherein the steps (i), (ii) and (iii) are performed in a continuous manner until a predetermined oxygen concentration in the sealable container is achieved for providing the inert environment in the sealable container.

5    30. The method of claim 29, further comprising compressing the withdrawn atmospheric air.

31. The method of claim 29 or claim 30, further comprising filtering the withdrawn atmospheric air.

10

32. The method of any one of claims 29 to 31, further comprising dehumidifying the withdrawn atmospheric air.

15    33. The method of any one of claims 29 to 32, further comprising providing fumigants in the sealable container.

34. The method of any one of claims 29 to 33, further comprising:

          ceasing performance of the steps (i), (ii) and (iii) once the predetermined oxygen concentration in the sealable container is achieved;

20

          monitoring an oxygen concentration in the sealable container; and

          restarting the steps (i), (ii) and (iii) if the oxygen concentration in the sealable container rises above the predetermined oxygen concentration.

25    35. The method of any one of claims 29 to 33, further comprising monitoring an ambient temperature in the sealable container.