
OXYGEN REDUCTION SYSTEM AND METHOD FOR OPERATING AN OXYGEN REDUCTION SYSTEM

Description

The present invention relates to an oxygen reduction system and a method for operating such a system.

An oxygen reduction system of the type according to the invention serves in particular for the controlled reduction of the oxygen content in the atmosphere of an enclosed area. For this purpose, the oxygen reduction system comprises a gas separation system for providing an oxygen-reduced gas mixture or inert gas respectively and a system of lines which is or can be fluidly connected to the gas separation system and to the enclosed area in order to feed at least some of the gas mixture or gas provided by the gas separation system to the enclosed area as needed.

The method or respectively system according to the invention serves for example to reduce the risk of and to extinguish fires in a protected room which is to be monitored, whereby to prevent or respectively fight fire, the enclosed room is also or can be rendered inert to different lowered levels on a sustained basis.

The fundamental principle of inerting technology for fire prevention is based on the understanding that in enclosed rooms which are only entered into occasionally by humans or animals and containing equipment which reacts sensitively when exposed to water, the risk of fire can be counteracted by lowering the oxygen concentration in the respective area to a value of, for example, approximately 15% by volume. At such a (reduced) oxygen concentration, most combustible materials can no longer ignite. The main fields of use of this inerting technology for fire prevention are accordingly also EDP areas, electrical switch and distribution rooms, enclosed facilities and storage areas with economic goods of particularly high value.

The fire prevention effect resulting from this method is based on the principle of oxygen displacement. Normal ambient air is known to consist of 21% by volume oxygen, 78% by volume nitrogen, and 1% by volume of other gases. For fire prevention purposes, the oxygen content in the spatial atmosphere of the enclosed room is reduced by introducing an oxygen-displacing gas, such as, for example, nitrogen. A fire prevention effect is known to start as soon as the oxygen content falls below the oxygen content of the normal ambient air. Depending on the combustible materials within the protected room, it may be necessary to further lower the oxygen content to, for example, 12% by volume.

A further application example for the oxygen reduction system or the method according to the invention is providing hypoxic training conditions in an enclosed room in which the oxygen content has been reduced. Such a room enables training under artificially simulated high-altitude conditions, also referred to as "normobaric hypoxic training."

A further application example is the storing of items, particularly foodstuffs, preferentially pomaceous fruit, in a so-called "controlled atmosphere (CA)" in which, among other things, the proportional percentage of atmospheric oxygen is regulated so as to slow the aging process acting on the perishable merchandise.

An oxygen reduction system of the type cited above is known in principle from the prior art. For example, printed publication DE 198 11 851 A1 describes an inerting system which is designed to lower the oxygen content in an enclosed room to a specific base inerted level and, in the event of a fire, to rapidly lower the oxygen content further to a specific fully inerted level.

The term "base inerted level" as used herein is to be understood as a reduced oxygen content compared to the oxygen content of normal ambient air, albeit whereby this reduced oxygen content poses no danger whatsoever to persons or animals such that they could still enter – at least briefly – into the permanently inerted area without any problem; i.e. without special safety precautions such as, for example, oxygen masks. The base inerted level corresponds for example to an oxygen content in the enclosed area of from 15-17% by volume.

On the other hand, the term "fully inerted level" is to be understood as an oxygen content which is further reduced compared to the oxygen content of the

base inerted level, one at which the flammability of most materials is already lowered to the extent they can no longer ignite. Depending on the fire load within the relevant area, the fully inerted level is usually at an oxygen concentration of approximately 12-14% by volume.

In order to equip an enclosed area with an oxygen reduction system, a corresponding inert gas source first needs to be provided in order to be able to provide the oxygen-reduced gas mixture or inert gas respectively which is to be introduced into the enclosed room. The output capacity of the inert gas source, i.e. the amount of inert gas which can be provided by the inert gas source per unit of time, is to thereby be adapted to the properties of the enclosed area, in particular the spatial volume and/or the airtightness of the enclosed area.

If the oxygen reduction system is employed as a (preventive) fire control measure, it is to be in particular ensured that, in the event of a fire, a sufficient amount of inert gas can be introduced into the spatial atmosphere of the enclosed area within the shortest time so that an extinguishing effect starts as quickly as possible.

Although the oxygen-reduced gas mixture / inert gas to be introduced into the enclosed area when required could be stored in a battery of high-pressure cylinders or similar compressed gas storage, "on-site production" of at least some of the oxygen-reduced gas mixture to be provided by the inert gas source has become accepted practice, particularly because storing inert gas in batteries of gas cylinders or similar compressed gas storage tanks requires special structural measures.

In order to be able to "produce" at least some of the oxygen-reduced gas mixture or inert gas to be provided by the inert gas source on site, the inert gas source usually comprises – in addition to a battery of high-pressure cylinders or similar compressed gas storage – a gas separation system in which at least a portion of the oxygen contained in an initial gas mixture fed to the gas separation system is separated off so that an oxygen-reduced gas mixture is provided at an outlet of the gas separation system.

The term "initial gas mixture" as used herein is to be generally understood as a gas mixture which, in addition to the oxygen component, in particular also contains nitrogen as well as, where appropriate, additionally gases (e.g. noble

gases). One conceivable initial gas mixture is for example normal ambient air; i.e. a gas mixture consisting of 21% by volume oxygen and 78% by volume nitrogen and 1% by volume of other gases. However, it is also conceivable to use some of the spatial air contained within the enclosed area as the initial gas mixture, whereby fresh air is preferably also added to the room's spatial air content.

The gas separation system serves in particular to maintain a reduced oxygen content at the corresponding level in the spatial atmosphere of an enclosed room. The output capacity of the gas separation system; i.e. the amount of oxygen-reduced gas mixture which can be provided per unit of time at the outlet of the gas separation system, is accordingly adapted in particular to the tightness of the enclosed area's spatial shell so that a corresponding sustaining flooding can be realized via the gas separation system.

On the other hand, it is advantageous in terms of the system design to not use or not only just use the gas separation system for the initial lowering of the oxygen content in the spatial atmosphere of the enclosed area since an initial lowering requires a relatively large amount of inert gas or oxygen-reduced gas per unit of time. To be able to realize this solely with a gas separation system, the gas separation system would have to be of correspondingly large configuration, which is generally not viable in terms of investment costs.

Therefore, in addition to the gas separation system, conventional oxygen reduction systems are usually provided with a compressed gas storage in which an oxygen-reduced gas mixture or inert gas is stored in compressed form. The gas mixture or inert gas respectively stored in this compressed gas storage serves in particular in rapidly lowering the oxygen content in the corresponding enclosed area so as to quickly lower the oxygen concentration in the event of a fire. It is however also conceivable to use the gas mixture / inert gas stored in the compressed gas storage for the initial lowering of the oxygen content in the corresponding enclosed area; i.e. for the initial reducing of the oxygen content to a specific inerted level.

The present invention is based on the problem posed after a conventional oxygen reduction system having been activated, i.e. when the oxygen-reduced gas mixture / inert gas stored in compressed form in the compressed gas storage has been introduced into the enclosed room for the rapid or initial lowering, a

replacement of the compressed gas storage which has then been emptied or partially emptied with a full compressed gas storage is then inevitable in order to ensure that the oxygen reduction system can also realize another rapid lowering according to a predefined sequence of events at a later point in time.

In many cases, however, replacing or changing the compressed gas storage can only be realized with increased effort since the compressed gas storage of an oxygen reduction system is often not disposed so as to be freely accessibly. Among other things, this circumstance often also leads to the ongoing costs of operating an oxygen reduction system being relatively high.

On the basis of this problem, the present invention is based on the task of further developing an oxygen reduction system of the type cited at the outset so as to further reduce the ongoing operating costs when operating the oxygen reduction system without compromising the effectiveness or efficiency of the oxygen reduction system.

This task can be solved by an oxygen reduction system in accordance with independent claim 1 and by a method for operating an oxygen reduction system in accordance with claim 51, whereby advantageous further developments of the inventive oxygen reduction system or inventive method respectively are indicated in the respective independent claims.

Accordingly, what is in particular proposed is an oxygen reduction system which comprises at least one gas separation system for providing an oxygen-reduced gas mixture at an outlet of the gas separation system as needed and a compressed gas storage for storing an oxygen-reduced gas mixture or inert gas in compressed form. The compressed gas storage is fluidly connected or connectable to at least one enclosed area by means of a line system in order to feed at least a portion of the gas mixture or respectively inert gas stored in the compressed gas storage to the at least one enclosed area when required. On the other hand, the outlet of the gas separation system is or can be fluidly connected selectively to an inlet of the compressed gas storage or to the at least one enclosed room in order to feed the gas mixture provided at the outlet of the gas separation system to the compressed gas storage and/or the at least one enclosed area as required.

The advantages able to be achieved with the inventive solution are obvious: By the outlet of the gas separation system being able to be fluidly connected selectively to an inlet of the compressed gas storage and/or to the at least one enclosed room in the inventive oxygen reduction system, the gas separation system is accorded a dual function. On the one hand, the gas separation system serves to feed an oxygen-reduced gas mixture to the spatial atmosphere of the enclosed area in order to lower the oxygen concentration in the spatial atmosphere of the enclosed area (= rapid or initial lowering) or to maintain the oxygen concentration at an already lowered level. On the other hand, the gas separation system serves in the refilling of at least one compressed gas cylinder of the compressed gas storage when required. This becomes necessary, for example, when at least some of the oxygen-reduced gas mixture or inert gas stored in compressed form in the compressed gas storage was previously introduced into the spatial atmosphere of the enclosed area, for example in order to rapidly lower the oxygen concentration therein to a specific inerted level. Such a rapid lowering by "shooting" an oxygen-reduced gas mixture / inert gas into the spatial atmosphere of the enclosed room becomes necessary in particular when the oxygen concentration in the enclosed room needs to be lowered as quickly as possible in the event of a fire or for the purpose of an initial lowering.

Due to the compressed gas storage or the at least one compressed gas cylinder of the compressed gas storage respectively being able to be subsequently refilled with an oxygen-reduced gas mixture via the gas separation system, replacing the compressed gas storage or the at least one compressed gas cylinder of the compressed gas storage or even refilling same by means of an external system is no longer necessary. The present solution is thus also particularly suitable for enclosed areas which are accessible only with difficulty such as those located in remote areas, for example.

In principle, the compressed gas storage or the compressed gas container(s) of the compressed gas storage respectively can now even be transported and positioned when in an empty state, which considerably simplifies transport and installation. The gas separation system then fills the compressed gas storage / compressed gas containers of the compressed gas storage with an oxygen-reduced gas mixture for the first time prior to the initial on-site startup.

In order to be able to optimize the capacity of the gas separation system, i.e. the amount of an oxygen-reduced gas mixture able to be provided per unit of time, and adapt it to the corresponding use, it is advantageous for there to be a compressor system upstream of the gas separation system by means of which an initial gas mixture to be fed to the gas separation system can be accordingly compressed. Depending on the mode of operation (VPSA or PSA), the degree of the initial gas mixture compression is thereby 1 to 2 bar or 8 to 10 bar respectively. However, other compressions are of course also conceivable.

The gas separation system is in particular designed to separate off at least some of the oxygen contained in the initial gas mixture.

Advantageously, the gas separation system is designed so as to be selectively operated in a VPSA operating mode or in a PSA operating mode.

As indicated above, the term "initial gas mixture" used herein is to be generally understood as a gas mixture which, in addition to the oxygen component, in particular also contains nitrogen and, where appropriate, additional gases such as for example noble gases. A conceivable initial gas mixture is for example normal ambient air; i.e. a gas mixture consisting of 21% by volume oxygen, 78% by volume nitrogen and 1% by volume of other gases. However, it is also conceivable to use some of the spatial air contained in the enclosed area as the initial gas mixture, whereby fresh air is preferably also added to said spatial air content.

To be generally understood by a gas separation system operating in VPSA mode is a system for providing nitrogen-enriched air which functions according to the principle of Vacuum Pressure Swing Adsorption (VPSA). In accordance with the invention, such a VPSA system is preferably used as the gas separation system in the oxygen reduction system but one able, however, to be operated in a PSA mode when needed. The "PSA" acronym stands for "pressure swing adsorption," normally denoting pressure swing adsorption technology.

In order to be able to switch the operating mode of the gas separation system from VPSA to PSA, a further development of the present invention provides for accordingly increasing the degree of compression of the initial gas mixture effected by the compressor system upstream of the gas separation system. It is in particular provided for the degree of compression to be increased when the

amount of an oxygen-reduced gas mixture to be provided per unit of time at the outlet of the gas separation system needs to be increased, particularly to a value which depends on the amount of the oxygen-reduced gas mixture to be provided per unit of time.

The increase in the compression of the initial gas mixture realized by the compressor system particularly occurs in the event of a fire; i.e. when for example a fire characteristic is detected in the spatial atmosphere of the enclosed area or when the oxygen content in the spatial atmosphere of the enclosed area is to be rapidly reduced further compared to a previously set or maintained oxygen content for some other reason. On the other hand, the increase in the compression realized by the compressor system also occurs when, for example, the compressed gas storage or the compressed gas cylinder of the compressed gas storage respectively needs to be refilled with an oxygen-reduced gas mixture.

It is generally provided for the gas separation system to comprise at least one nitrogen generator or a plurality of nitrogen generators connected in parallel. The at least one nitrogen generator is for example a nitrogen generator operated pursuant to PSA or VPSA technology. Specifically, a nitrogen generator based on PSA/VPSA technology comprises at least one adsorber vessel containing adsorber material which is designed to adsorb oxygen molecules when a gas containing oxygen passes through the adsorber vessel.

Alternatively or additionally to a nitrogen generator operated pursuant to PSA or VPSA technology, the gas separation system can also comprise at least one nitrogen generator based on membrane technology. Such a nitrogen generator generally uses a membrane system which capitalizes on the fact of different gases diffusing at different rates through certain materials. It is hereby conceivable to use a hollow fiber membrane with a separation material applied to the outer surface of the hollow fiber membrane through which oxygen can diffuse quite well whereas nitrogen only exhibits a low diffusion rate with this separation material. When air flows through the inside of a hollow fiber membrane prepared in this way, the oxygen contained in the air quickly diffuses outward through the hollow fiber wall while the nitrogen largely remains within the interior of the fiber so that a concentration of nitrogen occurs upon passage through the hollow fiber.

In accordance with embodiments of the inventive oxygen reduction system, the gas separation system is designed as a mobile system removable from the oxygen reduction system.

In accordance with embodiments of the inventive oxygen reduction system, same further comprises a compressor system upstream of the gas separation system for compressing an initial gas mixture to be fed to the gas separation system. It is hereby conceivable for the compressor system upstream of the gas separation system to be designed as a mobile system able to be removed from the oxygen reduction system and/or the gas separation system when needed.

In accordance with embodiments of the inventive oxygen reduction system, a compressor system is provided between the outlet of the gas separation system and the inlet of the compressed gas storage to compress as needed the oxygen-reduced gas mixture provided at the outlet of the gas separation system and to be fed to the compressed gas storage or the compressed gas cylinder(s) of the compressed gas storage respectively. It is also conceivable in this context for the compressor system provided between the outlet of the gas separation system and the inlet of the compressed gas storage to be designed as a mobile system able to be removed from the oxygen reduction system and/or the gas separation system when needed.

In accordance with embodiments of the inventive oxygen reduction system, a system of lines is provided by means of which the outlet of the gas separation system is or can be selectively fluidly connected to an inlet of the compressed gas storage and/or to the at least one enclosed area. The line system can thereby correspond at least in part to the line system via which the compressed gas storage is fluidly connected or connectable to the at least one enclosed area. Alternatively or additionally thereto, the line system via which the outlet of the gas separation system is or can be selectively fluidly connected to an inlet of the compressed gas storage and/or to the at least one enclosed area can be configured at least in part as a mobile system able to be removed from the oxygen reduction system and/or the gas separation system when needed.

In accordance with embodiments of the inventive oxygen reduction system, same further comprises a valve system having a first valve arrangement, wherein the first valve arrangement is designed to form and/or cut off a fluidic connection

between the outlet of the gas separation system and the inlet of the compressed gas storage.

In accordance with embodiments of the inventive oxygen reduction system, same comprises a valve system having a second valve arrangement, wherein the second valve arrangement is designed to form and/or cut off a fluidic connection between an outlet of the compressed gas storage and the at least one enclosed area.

In accordance with embodiments of the inventive oxygen reduction system, same comprises a valve system having a third valve arrangement, wherein the third valve arrangement is designed to form and/or cut off a fluidic connection between the outlet of the gas separation system and the at least one enclosed area.

The valve system of the aforementioned different embodiments of the inventive oxygen reduction system can be configured at least in part as a mobile system able to be removed from the oxygen reduction system and/or the gas separation system when needed.

In accordance with embodiments of the inventive oxygen reduction system, the compressed gas storage comprises at least one inlet and at least one outlet, wherein the inlet of the compressed gas storage and the outlet of the compressed gas storage are connected to the interior of the compressed gas storage via a connector piece. The connector piece can thereby be configured as a connector piece common to the at least one inlet and the at least one outlet. For example, the connector piece can be configured as T-piece or Y-piece. Alternatively or additionally thereto, the connector piece can be formed in a container valve of the compressed gas storage. For example, a pilot port of the container valve could in this case serve as the inlet of the compressed gas storage. Pilot ports are normally used to serially trigger the next of a compressed gas container. Their function does not apply in the case of parallel triggering.

In accordance with embodiments of the inventive oxygen reduction system, same further comprises a control device for the preferably coordinated control of controllable components of the oxygen reduction system. For example, the control device can be designed to control a valve system of the oxygen reduction system such that the outlet of the gas separation system is then preferably only fluidly connected to the inlet of the compressed gas storage when there is no

fluidic connection between the outlet of the compressed gas storage and the at least one enclosed area and/or no fluidic connection between the outlet of the gas separation system and the at least one enclosed area.

In accordance with embodiments of the inventive oxygen reduction system, same further comprises a sensor unit for coordinating the providing of the oxygen-reduced gas mixture at the outlet of the gas separation system, for coordinating the feed of the oxygen-reduced gas mixture at the outlet of the gas separation system to the compressed gas storage, for coordinating the feed of the oxygen-reduced gas mixture at the outlet of the gas separation system to the at least one enclosed area and/or for coordinating the feed of the oxygen-reduced gas mixture or inert gas respectively stored in the compressed gas storage to the at least one enclosed area.

In accordance with embodiments of the inventive oxygen reduction system, the oxygen reduction system comprises at least one pressure sensor allocated to the compressed gas storage for the as-needed or continuous detecting of a preferably static and/or dynamic gas pressure of the oxygen-reduced gas mixture or inert gas stored in the compressed gas storage.

In accordance with embodiments of the inventive oxygen reduction system, same comprises at least one pressure sensor allocated to the at least one enclosed area for the as-needed or continuous detecting of a preferably static gas pressure in the spatial atmosphere of the enclosed area.

In accordance with embodiments of the inventive oxygen reduction system, same comprises at least one pressure sensor for detecting a preferably dynamic and/or static gas pressure at the inlet of the compressed gas storage, in particular when the gas mixture provided at the outlet of the gas separation system is fed to the compressed gas storage.

In accordance with embodiments of the inventive oxygen reduction system, same comprises at least one temperature sensor allocated to the compressed gas storage for the as-needed or continuous detecting of a temperature of the oxygen-reduced gas mixture or inert gas stored in the compressed gas storage.

In accordance with embodiments of the inventive oxygen reduction system, same comprises at least one sensor allocated to the gas separation system for the as-needed or continuous detecting of a residual oxygen concentration in the oxygen-reduced gas mixture provided at the outlet of the gas separation system.

In accordance with embodiments of the inventive oxygen reduction system, the at least one gas separation system has a first operating mode, in which an oxygen-reduced gas mixture is fed when required to the compressed gas storage or to the at least one compressed gas container of the compressed gas storage respectively, and a second operating mode, in which an oxygen-reduced gas mixture is fed when required to at least one enclosed area, wherein the first and second operating mode can preferably be set by a control device and even more preferentially automatically, in particularly selectively automatically, by a control device.

In accordance with embodiments of the inventive oxygen reduction system, a compressor system is arranged upstream of the at least one gas separation system, wherein the upstream compressor system has a first operating mode, in which an oxygen-reduced gas mixture is fed when required to the compressed gas storage or to at least one compressed gas container of the compressed gas storage respectively, and a second operating mode, in which an oxygen-reduced gas mixture is fed when required to at least one enclosed area, wherein the first and second operating mode can preferably be set by a control device and even more preferentially automatically, in particularly selectively automatically, by a control device.

In accordance with embodiments of the inventive oxygen reduction system, the outlet of the gas separation system is connected or connectable to a first collecting line via a valve. It is in particular provided for the first collecting line and/or the valve to be designed as a mobile system able to be removed from the oxygen reduction system and/or the gas separation system as needed.

In accordance with embodiments of the inventive oxygen reduction system, the compressed gas storage comprises a plurality of spatially separated compressed gas containers connected together in parallel having at least one, preferably one respective container valve in each case. Hereby conceivable is for a first line section to be provided to preferably each of the plurality of compressed gas

containers, via which the respective container valve of the compressed gas container is fluidly connected to a first collecting line. The container valve of preferably each of the plurality of compressed gas containers is preferably fluidly connected in each case to a second collecting line via a second line section. In particular conceivable in this context is for the second collecting line to be fluidly connected or connectable to the at least one enclosed area via a valve, in particular an area valve. Preferably, the second collecting line and/or the valve is/are designed as a mobile system which is able to be removed from the oxygen reduction system and/or the gas separation system when needed.

In accordance with embodiments of the inventive oxygen reduction system, a control device is provided which is designed to preferably automatically, and even more preferentially, selectively automatically actuate the valve arrangements allocated to the oxygen reduction system in coordinated manner such that the outlet of the at least one gas separation system can be fluidly connected to the inlet of at least one compressed gas container when there is a fluidic connection between the outlet of at least one further compressed gas container and the at least one enclosed area.

In accordance with embodiments of the inventive oxygen reduction system, a control device is provided which is designed to preferably automatically, and even more preferentially, selectively automatically actuate the valve arrangements allocated to the oxygen reduction system in coordinated manner so as to selectively establish a fluidic connection between the inlet of the least one compressed gas container and the outlet of the gas separation system upon the detecting of a predetermined or determinable minimum pressure and/or upon at least one of the compressed gas containers falling below a predetermined or determinable minimum pressure.

In accordance with embodiments of the inventive oxygen reduction system, a backflow preventer, in particular designed as a check valve, is allocated to at least one compressed gas container to block a flow of gas to the compressed gas container from a line system running between the compressed gas container and the enclosed area.

In accordance with embodiments of the inventive oxygen reduction system, a backflow preventer, in particular designed as a check valve, is allocated to at

least one compressed gas container to block a flow of gas from the compressed gas container to a line system running between the outlet of the at least one gas separation system and the compressed gas container.

In accordance with embodiments of the inventive oxygen reduction system, at least one of the plurality of compressed gas containers comprises a container valve having a preferably pneumatically actuatable quick release valve arrangement for the as-needed establishing of a fluidic connection between the respective compressed gas container and a line system running between the compressed gas container and the enclosed area. Conceivable in this context is for the valve function of the quick release valve arrangement to be able to be switched off when required, particularly when the outlet of the gas separation system is or is to be connected to the inlet of the compressed gas container.

In accordance with embodiments of the inventive oxygen reduction system, the gas separation system comprises a first gas separator, for example in the form of a nitrogen generator, and at least one further second gas separator, for example likewise in the form of a nitrogen generator. Hereby conceivable is for the first gas separator to be configured as a gas separator intended to be stationary, whereby the at least one second gas separator is configured as a mobile gas separator. Alternatively conceivable thereto is for the first and the at least one second gas separator to each be configured as gas separators intended to be stationary. Further conceivable is for the first and the at least one second gas separator to each be configured as mobile gas separators.

In accordance with embodiments of the inventive oxygen reduction system, a sensor device is provided for monitoring the residual oxygen content of the oxygen-reduced gas mixture provided at the outlet of the gas separation system. Thereby conceivable is for a control device to be provided which is designed to only feed the oxygen-reduced gas mixture provided at the outlet of the gas separation system to the compressed gas storage or the at least one compressed gas container of the compressed gas storage respectively when the residual oxygen content of the oxygen-reduced gas mixture provided at the outlet of the gas separation system does not exceed a predefined or definable threshold.

In accordance with embodiments of the inventive oxygen reduction system, the nitrogen concentration of the oxygen-reduced gas mixture provided at the outlet

of the gas separation system can be switched between at least two predefined or definable values. Thereby conceivable is for the gas separation system to be designed to provide an oxygen-reduced gas mixture having a first nitrogen concentration at the outlet of the gas separation system when the oxygen-reduced gas mixture provided at the outlet of the gas separation system is to be fed to the at least one enclosed area and to provide an oxygen-reduced gas mixture having a second nitrogen concentration at the outlet of the gas separation system when the oxygen-reduced gas mixture provided at the outlet of the gas separation system is to be fed to the compressed gas storage or at least one compressed gas container of the compressed gas storage. The first nitrogen concentration is in particular thereby lower than the second nitrogen concentration. For example, the second nitrogen concentration amounts to at least 99% by volume.

According to a further aspect of the present invention, a compressor system is provided between the outlet of the gas separation system and the inlet of the compressed gas storage for the as-needed compressing of the oxygen-reduced gas mixture provided at the outlet of the gas separation system and to be fed to the compressed gas storage or at least one compressed gas container of the compressed gas storage respectively. Such a compression is necessary if, for example, the pressure of the gas mixture provided at the outlet of the gas separation system is not sufficient to achieve the desired compression for storing the gas mixture in the compressed gas storage.

The compressor system which is provided as required in order to accordingly further compress the oxygen-reduced gas mixture provided at the outlet of the gas separation system and to be fed to the compressed gas storage or the at least one compressed gas container of the compressed gas storage is preferably configured as a mobile system which can also be removed completely from the oxygen reduction system when needed, and particularly when a filling of the compressed gas storage, or at least one compressed gas container of the compressed gas storage respectively, is not necessary or not performed.

In this context it would for example be conceivable for the compressor system configured as a mobile system to be mounted or mountable on a transport pallet or similar structure able to be moved and/or loaded by means of a floor conveyor, e.g. a pallet truck or forklift, so as to enable the easiest possible removal of the compressor from the oxygen reduction system. Since in practice

the compressed gas storage commonly only needs to be filled occasionally, configuring the compressor system as a mobile system allows said compressor system to be used with different oxygen reduction systems, potentially also including those spatially separated from one another, in order to accordingly compress the oxygen-reduced gas mixture to be fed to a compressed gas storage to be filled at that site as needed.

It is to be emphasized here that according to one inventive concept for the refilling of the compressed gas storage, the oxygen-reduced gas mixture is in particular provided by a gas separation system, whereby the compressed gas storage is in particular a compressed gas cylinder or a battery of compressed gas cylinders. Furthermore, it is likewise possible for the compressed gas storage to exhibit any external shape taking into account the on-site spatial conditions and thus allowing an optimum use of the available space.

It is of course also conceivable and advantageous in this context for the gas separation system as well or only the gas separation system to be configured as a mobile system able to be removed from the oxygen reduction system (on site) when needed.

As already stated in conjunction with the compressor system, the term "mobile system" as used herein is in particular understood as a component which is integrated into the oxygen reduction system such that this component can be removed from the system without much effort. In particular, it is appropriate here for the component to be configured so as to be able to be moved by a floor conveyor or the like.

In one preferential realization of the inventive oxygen reduction system, same comprises a valve system having a first, a second and a third valve arrangement. The first valve arrangement is thereby configured so as to establish/disconnect a fluidic connection between the outlet of the gas separation system and the inlet of the compressed gas storage as required. The second valve arrangement of the valve system is configured so as to establish/disconnect a fluidic connection between the outlet of the compressed gas storage and the at least one enclosed area as required, while the third valve arrangement is configured to establish/disconnect a fluidic connection between the outlet of the gas separation system and the at least one enclosed area as required.

Thereby preferably provided for in a manner which is particularly easy to realize and yet effective is the inlet of the compressed gas storage and the outlet of the compressed gas storage being connected to the interior of the compressed gas storage by a preferably common connector piece, in particular in the form of a T-piece or Y-piece.

The inventive oxygen reduction system preferably comprises a control device for the coordinated actuating of the individual valve arrangements of the valve system. The control device is in particular constructed to actuate the individual valve arrangements of the valve system such that the outlet of the gas separation system is only fluidly connected to the inlet of the compressed gas storage, or to the inlet of at least one compressed gas container of the compressed gas storage respectively, when there is no fluidic connection between the outlet of the compressed gas storage and the at least one enclosed area and/or when there is no fluidic connection between the outlet of the gas separation system and the at least one enclosed area. Of course, setting a different priority is also conceivable in this context.

In some embodiments, two or even three separate control devices can also be provided: one for establishing/disconnecting the connection between the outlet of the gas separation system and the compressed gas storage or at least one compressed gas container of the compressed gas storage respectively (refill control) as well as one or two additional for establishing/disconnecting the connection between the outlet of the compressed gas storage and the enclosed room (controlling the initial or rapid lowering and full inertization) and between the outlet of the gas separation system and the enclosed room (controlling the base inertization or the maintaining of an oxygen concentration in the enclosed room respectively).

According to a further aspect of the inventive oxygen reduction system, it is provided for a sensor unit to be allocated to the control device. Preferably, the sensor unit is formed by at least one pressure sensor and/or at least one temperature sensor. In particular provided is for the pressure sensor and/or the temperature sensor to be able to measure the state, in particular the fill level or degree of filling respectively, of the compressed gas storage or at least one compressed gas container of the compressed gas storage respectively. During the

refilling of the compressed gas storage with oxygen-reduced gas mixture, the temperature inside the compressed gas storage or at least one compressed gas container of the compressed gas storage may increase, thus resulting in an incomplete refilling of the compressed gas storage with oxygen-reduced gas mixture after the refilling process due to the subsequent decrease in temperature and accompanying decrease in pressure.

The at least one pressure sensor and/or the at least one temperature sensor provided in particular in and/or on the compressed gas storage advantageously enables the control device to factor in temperature-dependent pressure conditions, e.g. when the compressed gas storage or at least one compressed gas container of the compressed gas storage is being preferably automatically refilled with oxygen-reduced gas mixture. In this regard, it is likewise conceivable for the control device to control the bleed of oxygen-reduced gas mixture from the compressed gas storage upon a temperature-dependent increase in pressure in the compressed gas storage or at least one compressed gas container of the compressed gas storage so as to prevent damage to the compressed gas storage.

In one preferential form of the inventive oxygen reduction system, the at least one gas separation system and/or the upstream compressor system has a first operating mode and a second operating mode for the as-needed feeding of oxygen-reduced gas mixture to the compressed gas storage or to at least one compressed gas container of the compressed gas storage respectively and/or the at least one enclosed area. It is preferably further conceivable to provide a respective independent gas separation system for each operating mode. Thus, the first and second modes of operation can in each case be individually or simultaneously realized by means of independent gas separation systems. The gas separation system or the operating mode of the at least one gas separation system and/or upstream compressor system can thereby preferably be controlled, in particular automatically, by the control device. It is to be noted in this regard that the compressed gas storage, or the at least one compressed gas container of the compressed gas storage respectively, is typically filled with an oxygen-reduced gas mixture having a higher nitrogen concentration than is required for the oxygen-reduced gas mixture fed to the enclosed area.

In so doing, the oxygen-reduced gas mixture of higher nitrogen concentration produced in the first operating mode of the gas separation system, preferably at

a nitrogen concentration of 99.5% by volume, can be used to refill the compressed gas storage. This oxygen-reduced gas mixture produced in the first operating mode of the gas separation system can at the same time optionally be used for the as-needed supplying of oxygen-reduced gas mixture to the enclosed area, same being able to be diluted for this purpose to a sufficient nitrogen concentration, in particular a nitrogen concentration of 95% by volume. Furthermore, the control device provides the opportunity of operating the gas separation system in a second mode of operation, wherein oxygen-reduced gas mixture of sufficient nitrogen concentration, preferably a nitrogen concentration of 95% by volume, is provided for the feed into the enclosed area.

It is thus conceivable that when refilling the compressed gas storage at a high nitrogen concentration, a portion of the oxygen-reduced gas mixture produced is fed to the enclosed area via a bypass. For example, the fluidic connection between the outlet of the gas separation system and the enclosed area can accordingly be used as a bypass in conjunction with the third valve arrangement. The bypass thereby preferably comprises an appropriate baffle to reduce the nitrogen concentration of the oxygen-reduced gas mixture to be fed to the enclosed area to an adequate level, for example by intermixing it with an initial gas mixture. The advantageous control of the gas separation system, preferably automatically by the control device, enables efficiently operating the gas separation system and optimally using the oxygen-reduced gas mixture as a function of the concentration provided.

Furthermore, utilizing two gas separation systems enables using one gas separation system in a first operating mode to refill the compressed gas storage and the other gas separation system in a second operating mode, particularly in parallel, to feed an oxygen-reduced gas mixture of an appropriately adequate nitrogen concentration to the enclosed area. Within the meaning of the present invention, a common or a respective individual upstream compressor system can thereby be provided as needed for multiple gas separation systems.

A further aspect of the inventive oxygen reduction system provides for the compressed gas storage to comprise a plurality of spatially separated compressed gas containers connected together in parallel having at least one, preferably one respective container valve in each case. In addition, a first as well as a second collecting line are provided. The outlet of the gas separation system is or can be

thereby connected to the first collecting line via a valve, while a first line section is preferably provided each of the plurality of compressed gas containers via which the respective container valve of the one or more compressed gas containers is fluidly connected to the first collecting line. The container valve of preferably each of the plurality of compressed gas containers is furthermore fluidly connected to the aforementioned second collecting line in each case via a second line section. The second collecting line itself is or can be fluidly connected to the at least one enclosed area via a valve, in particular an area valve.

In this embodiment, the valve via which the outlet of the gas separation system is or can be connected to the first collecting line forms the previously cited first valve arrangement. On the other hand, the valve via which the second collecting line is or can be fluidly connected to the at least one enclosed area is a part of the second valve arrangement if the oxygen reduction system is associated with multiple enclosed areas. If the oxygen reduction system is only assigned to a single enclosed area, however, the valve via which the second collecting line is or can be fluidly connected to the at least one enclosed area forms the second valve arrangement.

It can furthermore be provided for a plurality of compressed gas containers in the form of compressed gas cylinders or of any arbitrary geometric shape to be fluidly connected together for example via flexible hose connections or via rigid connections such as e.g. pipe connections, whereby one common container valve is provided per combination of multiple compressed gas containers into one unit. In particular with compressed gas containers of arbitrary external shape and adapted to the respectively spatial conditions, so doing gives rise to the possibility of making optimal use of the individually available space, whereby the number of container valves to be controlled can be reduced according to need.

The oxygen reduction system according to the invention is in particular suited to reducing, or respectively maintaining at a reduced value, the oxygen content in the spatial atmosphere in the case of multiple areas spatially separated from one another. According to a further development of the present invention, the oxygen reduction system is therefore associated with a plurality of spatially separated areas, wherein the aforementioned second valve arrangement has an assigned valve (in particular an area valve) for each of the plurality of areas via which the

second collecting line is or can be fluidly connected to the corresponding area in order to feed an oxygen-reduced gas mixture / inert gas to the area as required.

Provided in a further preferential form of the oxygen reduction system according to the invention is for the control device to control the individual valve arrangements in a coordinated manner such that the outlet of the at least one gas separation system can be fluidly connected to the inlet of at least one compressed gas container when the outlet of at least one further compressed gas container is fluidly connected to at least one enclosed area. The control device is accordingly designed, in particular in conjunction with the sensor unit, to selectively fill compressed gas containers with an oxygen-reduced gas mixture while the at least one enclosed area can be fed oxygen-reduced gas mixture from further compressed gas containers.

This thereby advantageously ensures a resource-friendly and time-optimized compressed gas container refilling with an oxygen-reduced gas mixture while simultaneously being able to maintain a concentration or concentration control range of an oxygen-reduced gas mixture in the enclosed area. Furthermore, the reliability of the oxygen reduction system is likewise improved by the selective refilling and control of the compressed gas containers provided by the control device.

In one preferential realization of the inventive oxygen reduction system, the control device is designed such that upon the detecting of a predefined minimum pressure and/or the falling below of a predefined minimum pressure in at least one of the plurality of compressed gas containers or compressed gas storage respectively, a fluidic connection is or can be selectively provided between the outlet of the gas separation system and the respective compressed gas container or compressed gas storage. The minimum pressure is freely selectable and serves to indicate the at least partial or complete depletion of a compressed gas container. Thus, the control device can determine a user-defined status or threshold level for refilling a compressed gas container or the compressed gas storage respectively based on a minimum pressure and, if applicable, initiate a corresponding refilling. As a result, a resource-saving compressed gas container or compressed gas storage refilling is ensured. Furthermore, it is thereby possible to detect leakages of e.g. the compressed gas storage when the control device detects a minimum pressure or a drop below said minimum pressure respectively in

at least one compressed gas container by way of the sensor unit and the control device preferably automatically starts a refilling of the compressed gas container with an oxygen-reduced gas mixture.

The invention is not solely limited to an oxygen reduction system but also relates to a method of operating an oxygen reduction system, in particular an oxygen reduction system of the above-described inventive type. The method first provides for storing an oxygen-reduced gas mixture or inert gas in compressed form in a compressed gas storage. To rapidly reduce the oxygen content in the spatial atmosphere of an enclosed area, at least some of the gas mixture or inert gas stored in compressed form in the compressed gas storage or in at least one compressed gas container of the compressed gas storage is then fed to the enclosed area and that by the compressed gas storage, or at least one compressed gas container of the compressed gas storage respectively, being fluidly connected to the enclosed area. In order to maintain a reduced oxygen content in the spatial atmosphere of the enclosed area and/or to further reduce the oxygen content in the spatial atmosphere of the enclosed area, an oxygen-reduced gas mixture provided at an outlet of a gas separation system is fed to the enclosed area in regulated manner and that by the outlet of the gas separation system being fluidly connected to the enclosed area.

Particularly provided in the operating method according to the invention is an at least partial refilling of the compressed gas storage, or at least one compressed gas container of the compressed gas storage respectively, following the initial lowering or rapid lowering of the oxygen content in the enclosed area by means of a feed of the gas mixture or inert gas compressed in the compressed gas storage and that by the outlet of the gas separation system being fluidly connected to the compressed gas storage or to the at least one compressed gas container of the compressed gas storage.

One preferential realization of the inventive method provides for at least a portion of the gas mixture or inert gas stored in compressed form in the compressed gas storage or in the at least one compressed gas container of the compressed gas storage respectively being fed to the enclosed area during the initial lowering or the rapid lowering of the oxygen content in the enclosed area such that the oxygen concentration in the enclosed area does not fall below a predefined or definable first value subject in particular to a fire load of the enclosed area and

does not exceed a likewise predefined or definable second value, wherein the second value is less than the value of the oxygen concentration in the normal atmosphere and greater than the first value. It is in particular conceivable in this context for the oxygen-reduced gas mixture provided at the outlet of the gas separation system during the sustained flooding occurring subsequent to the initial lowering or rapid lowering to be fed to the enclosed area in regulated manner such that the oxygen concentration in the enclosed area does not fall below the first value as predefined or definable in particular as a function of the fire load of the enclosed area and does not exceed the predefined or definable second value.

Preferably, the first and second predefined or definable oxygen concentration values correspond here to lower and upper limit values of a base inerted level of the enclosed area.

Provided according to a further aspect of the inventive method is for the oxygen-reduced gas mixture provided at the outlet of the gas separation system during the sustained flooding following the initial or rapid lowering to only be fed to the enclosed area in regulated manner when it has been preferably automatically verified, in particular by means of at least one fire detector, or manually verified, in particular by actuating a corresponding switch, that no fire is present within the enclosed area during or after the initial lowering and/or rapid lowering.

Provided in one preferential realization of the inventive method is the automatic verifying, in particular by means of at least one fire detector, and/or manual verifying, in particular by actuation of a corresponding switch, that a fire having broken out in the enclosed room has not been or not sufficiently suppressed subsequent the initial lowering or rapid lowering. It is thereby in particular provided that after verification that a fire which broke out in the enclosed room has not been or not sufficiently suppressed, the oxygen content in the spatial atmosphere of the enclosed area is further reduced and that done by feeding at least a portion of the gas mixture or inert gas stored in compressed form in the compressed gas storage or in at least one compressed gas container of the compressed gas storage to the enclosed area, and by fluidly connecting the compressed gas storage or at least one compressed gas container of the compressed gas storage to the enclosed area.

In particular conceivable in this context is that after verifying that a fire which had broken out in the enclosed room has not been or not sufficiently suppressed, the oxygen content in the spatial atmosphere of the enclosed area is continued to be reduced until the oxygen concentration in the enclosed area reaches a predefined or definable target concentration which corresponds to a nitrogen concentration at least as equally high as an extinguishing gas concentration dependent on the fire load of the enclosed area. The predefined or definable target oxygen concentration in the enclosed area thereby preferentially corresponds to a fully inerted level.

Alternatively or additionally conceivable in this context is maintaining the predefined or definable target oxygen concentration in the enclosed area (sustained flooding) subsequent the further reduction of the oxygen content in the spatial atmosphere of the enclosed area, and doing so by feeding an oxygen-reduced gas mixture provided at the outlet of the gas separation system to the enclosed area in regulated manner, and by the outlet of the gas separation system being fluidly connected to the enclosed area. During said sustained flooding, at least a partial refilling of the compressed gas storage or respectively at least one compressed gas container of the compressed gas storage preferentially occurs, and that by the inlet of the gas separation system being fluidly connected to the compressed gas storage or the at least one compressed gas container of the compressed gas storage respectively.

Provided according to a further aspect of the inventive method is for the enclosed area to be preferably continuously monitored or monitored at predefined or predefinable times/events with regard to the presence of at least one fire characteristic. Conceivable in this context is for at least the initial or respectively rapid lowering to be preferably automatically initiated as soon as at least one fire characteristic is detected.

According to a further aspect of the present invention, a control device is provided which is in particular designed to monitor the filling of the compressed gas storage or the at least one compressed gas container of the compressed gas storage respectively in coordinating or regulating manner. The at least partial refilling of the compressed gas storage / at least one compressed gas container of the compressed gas storage can in particular also take place simultaneously to the reduced oxygen content in the enclosed area being maintained and/or the

oxygen content in the enclosed area being further reduced. This aspect of the invention is thereby based on the realization that different conditions must be met when filling the compressed gas storage, particularly when it is in the form of a battery of compressed gas cylinders, in order to properly and safely fill the individual compressed gas cylinders of the battery of cylinders with the gas provided by the gas separation system.

Cited as just one example in this context is that there are different cylinder filling pressures for compressed gas cylinders. If a compressed gas cylinder is filled at the wrong pressure, the cylinder will not fill completely or an excess pressure will be generated which can damage the compressed gas cylinder (e.g. an excess pressure lid of the cylinder can then break).

The following will reference the accompanying drawings in describing example embodiments of the inventive oxygen reduction system in greater detail.

Shown are:

- Fig. 1 a schematic view of a first example embodiment of the oxygen reduction system according to the invention;
- Fig. 2 a schematic view of a second example embodiment of the oxygen reduction system according to the invention;
- Fig. 3 a schematic view of a container valve arrangement by means of which the respective compressed gas container is or can be connected to the first and second collecting line of the oxygen reduction system in the example embodiments;
- Fig. 4 a schematic view of a third example embodiment of the oxygen reduction system according to the invention;
- Fig. 5a a schematic block diagram to illustrate different example connections of a control device of one example embodiment of the inventive oxygen reduction system to components of the oxygen reduction system;

- Fig. 5b another schematic block diagram to illustrate different example connections of a control device of one example embodiment of the inventive oxygen reduction system to grouped components of the oxygen reduction system; and
- Fig. 6 a schematic flow chart of an example control sequence for controlling or respectively operating an oxygen reduction system according to one example embodiment of the invention.

The present invention is based on the problem of after a conventional oxygen reduction system having been activated; i.e. when the oxygen-reduced gas mixture or inert gas stored in compressed form in a compressed gas storage has been piped into an enclosed room for a rapid or initial lowering, the emptied compressed gas storage then usually has to be replaced. In many cases, however, replacing the compressed gas storage can only be realized at increased effort since the compressed gas storage of an oxygen reduction system is often not freely accessible. Among other things, this circumstance also leads to the ongoing operating costs of an oxygen reduction system often being relatively high. Additionally, if no reserve compressed gas storage is provided, fire protection cannot be ensured or not fully ensured while the compressed gas storage is being replaced.

In view of these problems, it is the task of the present invention to specify an oxygen reduction system in which its ongoing operating costs can be reduced without the effectiveness of the oxygen reduction system being compromised.

Accordingly proposed is an oxygen reduction system comprising at least one gas separation system for the as-needed providing of an oxygen-reduced gas mixture at an outlet of the gas separation system and one compressed gas storage, in particular in the form of one or more compressed gas containers, for storing an oxygen-reduced gas mixture or inert gas in compressed form. The compressed gas storage is fluidly connected or connectable via a line system to at least one enclosed area for the as-needed feeding of at least a portion of the gas mixture/ inert gas stored in the compressed gas storage to the at least one enclosed area. It is thereby provided for the outlet of the gas separation system to be fluidly connected or connectable selectively and/or when needed to an inlet of the compressed gas storage and/or to the at least one enclosed area for the as-

needed feed of the gas mixture provided at the outlet of the gas separation system to the compressed gas storage and/or to the at least one enclosed area.

In accordance with implementations of the oxygen reduction system, at least one control device is provided in order to at least partly automatically and in particular selectively automatically establish the fluidic connection between the outlet of the gas separation system and the inlet of the compressed gas storage and/or the at least one enclosed area.

The at least one control device is preferably a combined hardware/software mechanism. Input signals such as sensor measurements or user configuration inputs can be processed by the at least one control device and calculated by means of a control software, e.g. WAGNER OxyControl®. The control device can comprise a programmable logic control (PLC) such as available from Siemens AG, Munich, as the S7 or from WAGO Kontakttechnik GmbH, Minden, as type 750.

In accordance with embodiments of the inventive oxygen reduction system, the at least one control device is configured to receive sensor data, to provide information, e.g. by displaying or dispensing status or detector data, to actuate a compressor/compressor system and the gas separation system, and to actuate the valve arrangements associated with the oxygen reduction system.

In one embodiment, the valve arrangements comprise both electromagnetic control valves as well as pneumatic area valves. The control device is thereby configured to generate and to emit electrical actuation signals in order to actuate the electromagnetic control valves. The control valves are fluidly connected or connectable to a control gas source, e.g. a pilot gas cylinder or control gas cylinder. As soon as the control valves are actuated, control gas flows out of the pilot gas cylinder or control gas cylinder and actuates the pneumatic area valves as required.

In a further embodiment, an additional fire alarm control panel is provided as a secondary control device. The fire alarm control panel is configured so as to receive fire detection data from corresponding fire detectors, process fire alarm data and signal a fire alarm. One example fire alarm control panel can be obtained from Labor Strauss Sicherungsanlagenbau GmbH, Vienna, Austria. Both the control device as well as the fire alarm control panel can be configured so as

to be activated in the event of potentially dangerous conditions, e.g. smoke, fire or critical oxygen concentrations.

According to a further aspect of the oxygen reduction system, a sensor unit is allocated to the control device. The sensor unit preferably comprises at least one pressure sensor and/or at least one temperature sensor. In particular, the pressure sensor and/or the temperature sensor measure(s) the state of the compressed gas storage, in particular its fill level or respectively degree of filling. During the refilling of the compressed gas storage with an oxygen-reduced gas mixture, the temperature in the compressed gas storage can increase, which leads to an incomplete refilling of the compressed gas storage and thus also to a subsequent drop in pressure.

Preferentially, temperature-dependent pressure conditions in the compressed gas storage can be detected by means of the at least one pressure sensor and/or the at least one temperature sensor, as in particular provided in and/or on the compressed gas storage, and communicated to the control device so that the refilling of the compressed gas storage with oxygen-reduced gas mixture ensues subject to the temperature-dependent pressure conditions. In this regard, it is also conceivable for the control device to control or respectively regulate the release of oxygen-reduced gas mixture from the compressed gas storage in response to a temperature-dependent increase in pressure and thus prevent damage to the compressed gas storage.

In one embodiment of the oxygen reduction system, the at least one gas separation system and/or a compressor system arranged upstream of the gas separation system has a first operating mode and a second operating mode for feeding the oxygen-reduced gas mixture to the compressed gas storage and/or to the at least one enclosed area. Preferably, each operating mode is associated with an independent gas separation system. By so doing, the first and the second operating mode are individually or simultaneously operable by independent gas separation systems. To this end, the gas separation system or the operational mode of the at least one gas separation system and/or a compressor system arranged upstream of the gas separation system is preferably, in particular automatically, controlled by the control device. To be noted in this regard is that the refilling of the compressed gas storage with an oxygen-reduced gas mixture

is typically effected at a higher nitrogen concentration than is required for the feed to the enclosed area.

In this way, the oxygen-reduced gas mixture produced in a first gas separation system operating mode of higher nitrogen concentration, preferably at a nitrogen concentration of 99.5% by volume, can be used when needed to refill the compressed gas storage. The gas mixture produced in a first gas separation system operating mode can optionally also be used simultaneously to provide an oxygen-reduced gas mixture to the enclosed area, whereby the oxygen-reduced gas mixture is then diluted to a nitrogen concentration of e.g. 95% by volume.

The control device provides the further opportunity of operating the gas separation system in a second mode of operation in which an oxygen-reduced gas mixture having an effective nitrogen concentration, preferably a nitrogen concentration of 95% by volume, is provided which can then be fed to the enclosed area.

It is thus for example conceivable that when refilling the compressed gas storage at a high nitrogen concentration, a portion of the oxygen-reduced gas mixture generated is fed to the enclosed area via a bypass. For example, the fluidic connection between the outlet of the gas separation system and the enclosed area can be used as a bypass in conjunction with the third valve arrangement. For this purpose, the bypass preferably comprises an applicable baffle for reducing the nitrogen concentration of the oxygen-reduced gas mixture to be fed to the enclosed area to an effectual level or e.g. a mixing chamber in which the oxygen-reduced gas mixture is mixed with an initial gas mixture. Advantageously controlling the gas separation system, preferably automatically by the control device, enables the gas separation system to be operated efficiently and the optimal use of the oxygen-reduced gas mixture pursuant to the concentration as provided.

Furthermore, using two gas separation systems enables one gas separation system to be operated in a first mode of operation to refill the compressed gas storage and the other gas separation system to preferably be operated in parallel in a second mode of operation in order to provide the enclosed area with an oxygen-reduced gas mixture at an effectual nitrogen concentration. It is

conceivable for a common or an individual upstream compressor system to be provided for each of the gas separation systems.

According to a further aspect of the oxygen reduction system, a system is provided in which the compressed gas storage comprises a plurality of compressed gas containers connected parallel to one another and preferably each having at least one container valve. In addition, a first and a second collecting line are provided.

The outlet of the gas separation system is thus connected or connectable to the first collecting line via a valve, while a first line section is provided for preferably each of the plurality of compressed gas containers via which the respective container valve is fluidly connected to the first collecting line. The respective container valve of preferably each of the plurality of compressed gas containers is furthermore connected to the aforementioned second collecting line via a second line section. The second line section itself is fluidly connected or connectable to the at least one enclosed area via a valve, in particular an area valve.

In this embodiment, the valve via which the outlet of the gas separation system is or can be connected to the first collecting line forms the previously mentioned first valve arrangement. On the other hand, the valve via which the second collecting line is fluidly connected or connectable to the at least one enclosed area is a part of the second valve arrangement if the oxygen reduction system is associated with several enclosed areas. If, however, the oxygen reduction system is only assigned to a single enclosed area, the valve via which the second collecting line is fluidly connected or connectable to the at least one enclosed area forms the second valve arrangement.

Example embodiments of the invention will be described in the following referencing the accompanying drawings.

The first example embodiment of the inventive oxygen reduction system 100 depicted in Fig. 1 is characterized in particular by comprising a gas separation system 102 and a compressed gas storage 105 additionally thereto. The gas separation system 102 and the compressed gas storage 105 together form the "inert gas source" of the oxygen reduction system 100.

A compressor system 101 is provided upstream of the gas separation system 102 in order to accordingly compress the initial gas mixture to be fed to the gas separation system 102. By appropriately varying the pressure and volumetric flow of the initial gas mixture fed to the gas separation system 102, the gas separation system 102 can be adjusted to a stipulated nitrogen concentration and required volume of oxygen-reduced gas.

To be emphasized at this point, however, is that it is not necessarily imperative for a corresponding compressor system 101 to be connected upstream of the gas separation system 102.

The outlet of the gas separation system 102; i.e. the exit of the gas separation system 102, at which the oxygen-reduced gas mixture or nitrogen-enriched gas mixture respectively is provided, is fluidly connected or connectable to an enclosed room 107 by means of a first line system and connected or connectable to the aforementioned compressed gas storage 105 by means of an additional second line system. To that end, a first valve arrangement 104 is provided in the second line system; i.e. in the line system which connects the outlet of the gas separation system 102 to the compressed gas storage 105. A further valve arrangement 109 is provided in the line system which fluidly connects the outlet of the gas separation system 102 to the enclosed room 107. Yet another valve arrangement 106 is arranged in one line system which connects the compressed gas storage 105 to the enclosed area 107. So doing enables the compressed gas storage 105 to be fluidly connected to the enclosed area 107 when needed.

A control device 10 is preferably allocated to the oxygen reduction system 100 according to the invention in order to be able to control the individual valve arrangements 104, 106 and 109 in coordinated manner. The control device 10 is thereby further allocated a sensor unit having at least one pressure sensor and/or at least one temperature sensor which is/are in particular provided in and/or on the compressed gas storage. For the sake of clarity, the sensor unit is not depicted in Figs. 1 to 4.

Specifically, the depicted example embodiment provides for the control device 10 to be designed to control the individual valve arrangements 104, 106 and 109 such that the outlet of the gas separation system 102 is then preferably only fluidly connected or connectable to the inlet of the compressed gas storage 105

when there is no fluidic connection between the outlet of the compressed gas storage 105 and the at least one enclosed area 107; i.e. when the third valve arrangement 106 is closed. Moreover, the control device 10 is designed such that the outlet of the gas separation system 102 is then only fluidly connected or connectable to the compressed gas storage 105 via the first valve arrangement 104 when there is no fluidic connection between the outlet of the gas separation system 102 and the enclosed area 107; i.e. when the second valve arrangement 109 is closed.

It is alternatively also possible to provide the inventive oxygen reduction system 100, in particular the control device 10, such that the outlet of the gas separation system 102 can when needed be fluidly connected simultaneously to the inlet of the compressed gas storage 105 via the first valve arrangement 104 and to the enclosed area 107 via the second valve arrangement 109.

In the example embodiment of the inventive oxygen reduction system 100 depicted schematically in Fig. 1, a further compressor system 103 is provided which is arranged in the line system connecting the outlet of the gas separation system 102 to the compressed gas container 105. This further compressor system 103 enables the oxygen-reduced gas mixture provided at the outlet of the gas separation system 102 to be compressed further as needed so it can then be stored in compressed gas container 105 in the desired compressed form. If a compressed gas cylinder or a battery of cylinders is used as the compressed gas container, it is advantageous for the further compressor system 103 to compress the oxygen-reduced gas mixture provided at the outlet of the gas separation system 102 up to 300 bar.

The oxygen reduction system 100 depicted schematically in Fig. 2 differs from the schematically depicted embodiment in Fig. 1 particularly in that the oxygen reduction system 100 according to the embodiment depicted in Fig. 2 is not allocated to only one single enclosed area 107, but rather to a plurality of enclosed areas 107a, 107b. The oxygen reduction system 100 is thus realized as a so-called multi-zone system.

A further difference to the embodiment depicted in Fig. 1 is that the compressed gas storage 105 of the oxygen reduction system 100 depicted schematically in Fig. 2 comprises a plurality of spatially separated compressed gas containers

105a, 105b, 105c, 105d connected in parallel. These compressed gas containers are e.g. commercially available high pressure cylinders (300 bar cylinders).

The individual compressed gas containers 105a to 105d are connected in parallel to each other so as to be able to supply the gas mixture stored in compressed form in these compressed gas containers 105a to 105d to the enclosed area(s) 107a, 107b as rapidly as possible when needed.

A first collecting line 110 as well as a second collecting line 111 is used for the parallel connection of the compressed gas containers 105a to 105d in the embodiment depicted schematically in Fig. 2. The first collecting line 110 can be fluidly connected to the outlet of the gas separation system 102 via the first valve arrangement 104.

As also in the embodiment depicted schematically in Fig. 1, the oxygen reduction system 100 shown in Fig. 2 employs a further valve arrangement to connect the outlet of the gas separation system 102 to the first enclosed area 107a and/or the second enclosed area 107b as needed. In contrast to the embodiment depicted schematically in Fig. 1, however, this valve arrangement comprises a total of two valves 109a and 109b, each designed as an area valve and allocated to one of the respective enclosed areas 107a, 107b.

The aforementioned second collecting line 111 is likewise fluidly connectable to the respective enclosed areas 107a, 107b via corresponding area valves 106a, 106b. These valves 106a, 106b are likewise preferably designed as area valves.

The following will reference the schematic representation in Fig. 3 in also describing the parallel connection of the individual compressed gas containers 105a to 105d in greater detail.

Specifically, provided in the embodiment depicted schematically in the drawings is for each compressed gas container 105a to 105d to be provided with a corresponding container valve 108 (see Fig. 3). Each container valve 108 of the compressed gas container 105a to 105d is fluidly connected to the first collecting line 110 on one side via a first line section and to the second collecting line 111 on the other side via a second line section.

A connector piece 113, in particular in the form of a T-piece or Y-piece, is allocated to each container valve 108 of compressed gas containers 105a to 105d for that purpose, via which the respective first line section on the one side and the respective second line section on the other side is fluidly connected to the respective container valve 108 or the interior of the compressed gas container 105a to 105d respectively.

Preferentially, the container valves 108 of compressed gas containers 105a to 105d are in each case implemented as a quick-release valve assembly, in particular as a pneumatically actuatable quick-release valve assembly, in order to establish a fluidic connection between the respective compressed gas containers 105a to 105d and the second collecting line as needed. It is thereby of advantage for the valve function of the quick-release valve assembly to also be able to be disabled when required, and that in particular when the outlet of the gas separation system 102 is or is to be connected to the inlet of the respective compressed gas containers 105a to 105d for the purpose of refilling.

As schematically indicated in Fig. 3, it is further conceivable for at least one backflow preventer 112 to be provided between the container valve 108 of the respective compressed gas container 105a to 105d and the first and/or second collecting line 111, and in particular the first and/or second line section, in order to block a flow of gas from the second collecting line 111 back into the compressed gas containers 105a to 105d and/or from the compressed gas containers 105a to 105d to the first collecting line 110. According to Fig. 3, the two backflow preventers 112 can be directly provided on a connector piece 113, in particular a T-piece, and fluidly connected to the container valve 108 of the respective compressed gas container 105a to 105d. The inlet of the compressed gas storage and the outlet of the compressed gas storage are then connected to the interior of the compressed gas storage by a preferably common connector piece 113. So doing basically ensures that no return flow from the second collecting line 111 into one of the compressed gas containers 105a to 105d will occur when the quick-release valve assembly is activated, for example when one of the compressed gas containers 105a to 105d is at lower pressure compared to the other compressed gas container.

The embodiment depicted schematically in Fig. 4 differs from the embodiment in Fig. 2 particularly by the further compressed gas containers 105e to 105f which

are able to be fluidly connected to the outlet of the gas separation system by a further valve of the first valve arrangement 104. The control device pursuant to the present invention is to thereby be designed to accordingly control multiple valves of the first valve arrangement 104.

Just as for the compressed gas containers 105a to 105d in Fig. 2, the further compressed gas containers 105e to 105f shown in Fig. 4 are provided with a further first collecting line 110 and a further second collecting line 111. Each of the further compressed gas containers 105e to 105f are also assigned a container valve 108 with a connector piece 113, particularly in the form of a T-piece or a Y-piece, via which the respective first line section on the one side and the respective second line section on the other side is fluidly connectable to the respective container valve 108 or to the interior of the further compressed gas container 105e to 105f respectively.

The further second collecting line 111 is likewise fluidly connectable to the respective enclosed areas via corresponding area valves 106c, 106d. These valves 106c, 106d are preferably likewise designed as area valves.

On the basis of the embodiment of the present invention schematically depicted in Fig. 4, it is advantageously possible to implement the further compressed gas containers 105e to 105g and compressed gas containers 105a to 105d as being controlled or regulated by the control device 10 preferably independently of each other. In particular, e.g. the further compressed gas containers 105e to 105g can be refilled subsequent a rapid and/or initial lowering while, at the same time, the compressed gas storages 105a to 105d are connected to the enclosed areas 107a, 107b in order to maintain or further lower a reduced oxygen content in the enclosed areas 107a, 107b.

Of course, the compressed gas containers 105a to 105d can also be refilled with oxygen-reduced gas mixture from the gas separation system 102 while the further compressed gas containers 105e to 105g are fluidly connected to the enclosed areas 107a, 107b. Moreover, the use of further compressed gas containers 105e to 105g is not limited to the number of compressed gas containers as depicted in Fig. 4 but rather can be for example supplemented by further compressed gas containers or further independently controllable assemblages of multiple compressed gas containers respectively.

The embodiment shown in Fig. 4 advantageously enables multi-stage inertization. In multi-stage inertization, the compressed gas containers 105a to 105d first lower the oxygen concentration to a base inerted level in the event of a fire and this level is maintained for example by an oxygen-reduced gas mixture produced by the gas separation system 102 being introduced into the enclosed area 107. After a predefinable or defined interval of time, a recheck is made as to whether a fire is still present, for example by means of fire detectors or visual verification. If there is no longer any fire, the base inerted level is maintained for a further definable or defined interval of time so as to prevent a re-ignition. If, however, fire is still present, the oxygen concentration is lowered to a fully inerted level by means of the further compressed gas containers 105e to 105g and maintained at that level by means of the gas separation system 102.

In particular provided is for the compressed gas storage 105, or the at least one compressed gas container 105a-g of the compressed gas storage 105 respectively, to be at least partially refilled subsequent the initial lowering or a rapid lowering of the oxygen content within the enclosed area 107a, 107b by the introducing of the compressed gas mixture or inert gas into the at least one compressed gas storage 105 or the at least one compressed gas container 105a-g of the compressed gas storage 105, and that by fluidly connecting the outlet of the gas separation system 102 to the compressed gas storage 105 or the at least one compressed gas container 105a-g of the compressed gas storage 105 respectively.

One preferential realization provides for at least a portion of the gas mixture or inert gas stored in compressed form in the compressed gas storage 105 or the at least one compressed gas container 105a-g of the compressed gas storage 105 to be fed to the enclosed area 107a, 107b during the initial lowering or the rapid lowering of the oxygen content in the enclosed area 107a, 107b such that the oxygen concentration in the enclosed area 107a, 107b does not fall below a predefined or definable first value which is in particular dependent on the fire load of the enclosed area 107a, 107b nor exceed a likewise predefined or definable second value, wherein the second value is less than the oxygen concentration value of the normal atmosphere and greater than the first value. Particularly conceivable in this context is for the oxygen-reduced gas mixture provided at the outlet of the gas separation system 102 during the sustained flooding subsequent the initial or rapid lowering to be fed to the enclosed area

107a, 107b in such a manner that the oxygen concentration in the enclosed area 107a, 107b does not fall below the predefined or definable first value particularly dependent on the fire load of the enclosed area 107a, 107b and does not exceed the likewise predefined or definable second value.

Preferably, the first and second predefined or definable oxygen concentration values correspond here to lower and upper limit values of a base inerted level of the enclosed area.

Provided according to a further aspect is for the oxygen-reduced gas mixture provided at the outlet of the gas separation system 102 during the sustained flooding subsequent the initial lowering or rapid lowering to then only be fed in regulated manner to the enclosed area 107a, 107b if it has been verified during or after the initial lowering / rapid lowering, preferably automatically, in particular by means of at least one fire detector 118, and/or manually, in particular by actuating a corresponding switch, that no fire is present in the enclosed area 107a, 107b.

One preferential realization provides for automatically verifying, in particular by means of at least one fire detector 118, and/or manually verifying, in particular by actuating a corresponding switch, that a fire having broken out in the enclosed room 107a, 107b has not been or not sufficiently suppressed subsequent the initial lowering / rapid lowering. Hereby in particular provided is for the further reducing of the oxygen content in the spatial atmosphere of the enclosed area 107a, 107b following verification that a fire which broke out in the enclosed area 107a, 107b has not been or not sufficiently suppressed, and that by at least a portion of the gas mixture or inert gas stored in compressed form in the compressed gas storage 105, or respectively at least a portion of the gas mixture or inert gas stored in compressed form in at least one compressed gas container 105a-g of the compressed gas storage 105 being fed to the enclosed area 107a, 107b, and namely by fluidly connecting the compressed gas storage 105, or the at least one compressed gas container 105a-g of the compressed gas storage 105 respectively to the enclosed area 107a, 107b.

Particular conceivable in this context is for the further reducing of the oxygen concentration in the spatial atmosphere of the enclosed area 107a, 107b, following verification of a fire having broken out in the enclosed area 107a, 107b

not having been or not sufficiently suppressed, to continue until the oxygen concentration in the enclosed area reaches a predefined or definable target concentration corresponding to a nitrogen concentration which is at least equally as high as an extinguishing gas concentration dependent on the fire load of the enclosed room 107a, 107b. The predefined or definable oxygen target concentration in the enclosed area 107a, 107b thereby preferentially corresponds to a fully inerted level.

Alternatively or additionally conceivable in this context is for the predefined or definable oxygen target concentration in the enclosed area 107a, 107b to be maintained (sustained flooding) subsequent the further reducing of the oxygen content in the spatial atmosphere of the enclosed area 107a, 107b, and that by feeding an oxygen-reduced gas mixture provided at the outlet of the gas separation system 102 in regulated manner to the enclosed area 107a, 107b, and namely by fluidly connecting the outlet of the gas separation system 102 to the enclosed area. At least a partial refilling of the compressed gas storage 105 or a refilling of at least one compressed gas container 105a-g of the compressed gas storage 105 thereby preferentially occurs during said sustained flooding, and that by the outlet of the gas separation system 102 being fluidly connected to the compressed gas storage 105 or to at least one compressed gas container 105a-g of the compressed gas storage 105 respectively.

Provided according to a further aspect of the inventive method is for the enclosed area 107a, 107b to be preferably continuously monitored or monitored at predefined or predefinable times or events with regard to the presence of at least one fire characteristic. Conceivable in this context is for at least the initial or respectively rapid lowering to be preferably automatically initiated as soon as at least one fire characteristic is detected.

Fig. 5a shows a schematic block diagram illustrating different example connections of a control device 10 to components of the oxygen reduction system 100 according to one example embodiment. The control device 10 receives inputs via different sensors. The sensor unit identified by the reference numeral "114" furnishes the control device 10 with data from a temperature sensor 115 and a pressure sensor 116 located within, at or on a compressed gas container 105. By calculating the temperature and pressure data, the control device 10 can effect a more precise refilling in response to a temperature-dependent increase in pressure

in the compressed gas container 105. Moreover, the pressure sensor 116 enables the control device 10 to detect a drop in pressure in the compressed gas container 105, which can be a trigger condition for starting the refilling.

The oxygen sensor 117 furnishes the control device 10 with values from an oxygen concentration measurement in the enclosed area 107a, 107b, whereby control of the activation or deactivation of the gas separation system 102 and/or the upstream compressor system 101 is possible as a function of the current oxygen concentration.

An optional fire alarm control panel 121 can also be connected to the control device 10 in order to trigger a fire alarm mode of the control device 10, whereby the fire alarm mode includes for example the triggering of the oxygen reduction system's extinguishing mode. The extinguishing mode comprises lowering the oxygen concentration in the enclosed area 107a, 107b to a base or fully inerted level. A fire detector 118, which in this case is an aspirating smoke detector, is configured to furnish alarm information to the fire alarm control panel 121 when smoke or fire is detected in an enclosed area 107a, 107b in order to enable the earliest possible detection of smoke in the enclosed area 107a, 107b. In the case of potentially dangerous conditions, e.g. smoke, fire or critical oxygen concentrations, the control device 10 and the fire alarm control panel 121 are configured to trigger the alarm means 119.

It is possible to display the available information in the control device 10 via a user interface 120, e.g. status or alarm information, and for the control device 10 to execute intended user inputs, for example configuration inputs. The control device 10 is moreover connected to an upstream compressor system 101 in order to activate or deactivate said compressor system 101 or to increase or lower the compression level of the compressor system 101.

The control device 10 is further connected to a downstream compressor system 103 in order to activate said compressor system 103 for the refilling of the compressed gas container 105 and to deactivate it when the refilling is finished. In order to enable the control device 10 to be able to control the base inerted mode, the rapid oxygen concentration lowering mode (for fully inerting) and the refilling mode, the control device 10 is connected to valves 104, 106 and 109 and can change the open or close position of said valves 104, 106 and 109.

Fig. 5b shows the components of Fig. 5a in a grouped overview as well as the communication directions between the control device 10 and the other connected components.

The control device 10 exchanges signals with the sensor unit 114 which in this example embodiment comprises at least one temperature sensor 115 for measuring and/or monitoring the temperature of the compressed gas storage 105, at least one pressure sensor 116 for measuring and/or monitoring the pressure of the compressed gas storage 105, at least one oxygen sensor 117 for measuring and/or monitoring the oxygen concentration in the atmosphere of the enclosed area 107a, 107b as well as at least one oxygen sensor 122 for measuring and/or monitoring the residual oxygen concentration at the outlet of the gas separation system 102.

The control device 10 additionally exchanges signals with the fire alarm control panel 121, which in turn communicates with at least one fire detector 118, in order to signal a fire as detected by a fire detector 118, e.g. to a primary control unit or the control device 10 of the oxygen reduction system. The fire alarm control panel 121 additionally controls alarm means 119a in order to draw the attention of people to the fire. The alarm means 19a can for example be flashing lights, illumination panels and/or signal horns.

The control device 10 can likewise control its own or respectively additional alarm means 119b when, for example, the oxygen concentration within the enclosed area 107a, 107b as measured by the at least one oxygen sensor 117 exceeds or falls short of an inadmissibly high or inadmissibly low concentration.

The control device 10 additionally exchanges signals with the user interface 120, shown as an example in the present figure as a touch panel mounted on the control device 10. The user interface 120 displays for example configuration, status and alarm data to the user and enables, for example, the setting up or customizing of the control functions of the control device 10 via user inputs. For instance, threshold values for the sensors of the sensor device 114 can be specified or changed via the user interface 120, whereby falling short of or exceeding the thresholds can lead to a signaling or to the activating of alarm means 119b.

The control device 10 additionally exchanges signals with the gas separation system 102, for example switching it on or off or querying the status of the gas separation system 102. The compressor systems 101, 103 arranged upstream and downstream of the gas separation system 102 are also activated via the control device 10, e.g. their switching on and off or stepped or stepless increasing or decreasing of the compression level.

Moreover, the control device 10 controls the valves of the first, second and third valve arrangements 104, 106 and 109, e.g. the opening or closing of the valves, in order to selectively establish or disconnect fluidic connections between the gas separation system 102, the compressed gas storage 105 and the enclosed area 107a, 107b.

Fig. 6 shows a flow chart of an example control sequence for controlling an oxygen reduction system as shown for example in Fig. 1.

The left branch of Fig. 6 shows a sequence for the initial lowering and/or maintaining of an oxygen-reduced concentration in the enclosed areas 107a, 107b ("base inerted" mode). The right branch of Fig. 6 shows a sequence for fire detection, fire extinguishing ("fully inerted" mode) and refilling of the compressed gas containers 105a to 105d.

Both sequences are shown for the example of enclosed area 107a. Such sequences are of course also conceivable for enclosed area 107b. Both sequences as shown in the left and right branch of Fig. 6 can occur individually or in parallel.

The following description refers to the left branch in Fig. 6 ("base inerted" mode):

The oxygen concentration within the enclosed area 107a, 107b is continuously measured during the operation of the oxygen reduction system and the measurement data is furnished to the control device 10. Upon a preset maximum oxygen concentration being reached, the control device 10 opens valve 109a and starts the upstream compressor system 101; i.e. upstream of the gas separation system 102, as well as gas separation system 102 in order to feed an oxygen-reduced gas mixture to the enclosed area 107a. As soon as a preset minimum

concentration of oxygen is reached, the control device 10 stops the upstream compressor system 101 and the gas separation system 102 and closes valve 109a.

Since the oxygen concentration rises naturally due to leaks in the enclosed areas 107a, 107b, it eventually will reach a maximum concentration; thus thereby triggering a restart of the upstream compressor system 101 and the gas separation system 102.

The minimum and maximum concentration can be individually defined and stored in the control device 10. An example minimum concentration could be 17.0% by volume and an example maximum concentration could be 17.4% by volume, which would correspond to a typical base inerting range.

A further example incorporates lower and upper limit values of 14.0% by volume and 14.4% by volume, which would correspond to a typical full inerting range. The minimum and maximum concentrations can also be variably defined for day and night mode in order to increase the fire protection efficiency, wherein the day mode represents a time with high human traffic within the enclosed area, requiring a higher oxygen concentration, and wherein the night mode represents a time in which only few or no people enter into the enclosed area, which enables a lower oxygen concentration.

The following description refers to the right branch of Fig. 6 which shows the reciprocal action between fire detection, fire extinguishing ("fully inerted" mode) and refilling:

The fire detection can be realized with aspirating smoke detectors, whereby a very practical, reliable and visually attractive fire alarm system can be realized. If a fire is detected within the enclosed area 107a, the detection signal is transmitted from the fire alarm control panel 121 to the control device 10. The control device 10 consequently opens valve 106a and activates compressed gas containers 105a to 105d to discharge via a collecting line 111 and valve 106a so that the oxygen-reduced gas mixture stored in the compressed gas containers 105a to 105d quickly enters into the enclosed area 107a and thereby extinguishes the fire.

As soon as the oxygen concentration in the enclosed area 107a reaches a minimum, the extinguishing or full inerting mode is ended by closing valve 106a. The refilling begins automatically or manually with the opening of valve 104 and the starting of the downstream compressor system 103.

Container pressure is measured continuously and the measurement data fed to the control device 10. The compressed gas containers 105a to 105d are refilled until the pressure reaches a preset maximum. In one preferential embodiment, the pressure measurements are subject to temperature compensation. This is done both by measuring pressure and measuring temperature in the compressed gas containers 105a to 105d and by calculating a standardized pressure in accordance with thermodynamic formulas. The minimum and maximum pressure can be individually defined and stored in the control device 10.

The refilling is completed by the control device 10 stopping the downstream compressor system 103 and closing valve 104. The system then reverts to a mode in which the system reacts sensitively to fire alarm signals furnished in respect of the enclosed area 107a, 107b, thus to a standby state for further rapid lowering or full inerting in the event of a re-ignition or another fire.

The invention is not limited to the embodiments of the oxygen reduction system 100 depicted schematically in the drawings but rather yields from an integrated consideration of all the features disclosed herein.

Also particularly conceivable in this context is for another buffer storage to be provided directly at the outlet of the gas separation system in order to temporarily store the oxygen-reduced gas mixture provided at the outlet of the gas separation system.

Provided according to preferential realizations of the oxygen reduction system 100 is making use of a gas separation system (nitrogen generator) which remains stationary with the required additional downstream high pressure compressor (compressor system 103) likewise being kept stationary or being provided so as to be mobile.

Should, however, the additional structural investment (high-pressure filling lines, valves, etc.) not be worthwhile for particular applications, a fully mobile variant (gas separation system 102, both compressor systems 101, 103) is of advantage.

In one alternative, a stationary gas separation system could be supported by a mobile gas separation system since the stationary gas separation system would otherwise need to be dimensioned larger just for a potential refilling in order to produce the necessary supply output. The possibility of providing two stationary gas separation systems (one for sustained flooding, one for refilling) is in principle likewise conceivable.

If (only) one, in particular stationary, gas separation system is provided, it is advantageous to be able to switch the nitrogen concentration of the oxygen-reduced gas mixture providable at the outlet of the gas separation system. Proven in terms of optimum supply conditions when being introduced into the room is a nitrogen concentration of approx. 95% by volume; desirable for the filling, however, is at least 98% by volume, preferentially at least 99% by volume, in order to optimize the number of gas pressure containers.

In addition to the pressure of the gas stored in the compressed gas storage (cylinder pressure), it is of advantage to monitor the temperature of the compressed gas storage (cylinder temperature). This not only serves the temperature-compensated pressure measurement or filling respectively but also the terminating of filling upon a maximum temperature being exceeded so as to protect the container valves. The temperature can be measured by means for example of magnetic thermoelements on the outer wall of the cylinders. The temperature is preferentially measured at least at two compressed gas storage points; i.e. the coldest and the warmest spot. The coldest and the warmest spot can be determined beforehand by testing or can be estimated based on the surrounding conditions, e.g. on the basis of cool wall surfaces or radiators. The temperature at the coldest spot then serves the temperature-compensated pressure measurement/filling whereas the measurement at the warmest spot seeks to prevent the exceeding of a maximum temperature potentially damaging to the container valves.

It is moreover of advantage to monitor the residual oxygen content at the outlet of the gas separation system in order for the nitrogen-reduced air to not be

conducted into the compressed gas storage but rather diverted to the outside or into the enclosed area in the event of inadmissibly low nitrogen concentration so as to ensure the required purity.

List of reference numerals

10	control device
100	oxygen reduction system
101	upstream compressor system
102	gas separation system
103	downstream compressor system
104	first valve arrangement
105	compressed gas storage
105a-g	compressed gas container
106, 106a-d	third valve arrangement / third valve arrangement valves
107, 107a,b	enclosed area
108	container valve
109, 109a,b	second valve arrangement / second valve arrangement valves
110	first collecting line
111	second collecting line
112	backflow preventer
113	connector piece
114	sensor unit
115	temperature sensor
116	pressure sensor
117	oxygen sensor (area)
118	fire detector
119a, 119b	alarm means
120	user interface
121	fire alarm control panel
122	oxygen sensor (gas separation system)

Claims

1. An oxygen reduction system (100), comprising the following:
 - at least one gas separation system (102) for providing an oxygen-reduced gas mixture at an outlet of the gas separation system (102) as needed; and
 - a compressed gas storage (105; 105a-g), particularly in the form of one or more compressed gas containers, for storing an oxygen-reduced gas mixture or inert gas in compressed form,

wherein the compressed gas storage (105; 105a-g) is fluidly connected or connectable to at least one enclosed area (107; 107a, 107b) by means of a line system in order to feed at least a portion of the gas mixture or respectively inert gas stored in the compressed gas storage (105; 105a-g) to the at least one enclosed area (107; 107a, 107b) when needed;

wherein the outlet of the gas separation system (102) is or can be fluidly connected selectively to an inlet of the compressed gas storage (105; 105a-g) and/or to the at least one enclosed area (107; 107a, 107b) in order to feed the gas mixture provided at the outlet of the gas separation system (102) to the compressed gas storage (105; 105a-g) and/or the at least one enclosed area (107; 107a, 107b) when needed; and

wherein the oxygen reduction system (100) further comprises a sensor unit (114) for coordinating the providing of the oxygen-reduced gas mixture at the outlet of the gas separation system (102), for coordinating the feed of the oxygen-reduced gas mixture provided at the outlet of the gas separation system (102) to the compressed gas storage (105; 105a-g), for coordinating the feed of the oxygen-reduced gas mixture provided at the outlet of the gas separation system (102) to the at least one enclosed area (107; 107a, 107b), and/or for coordinating the feed of the oxygen-reduced gas mixture/inert gas stored in the compressed gas storage (105; 105a-g) to the at least one enclosed area (107; 107a, 107b),

wherein the gas separation system (102) is preferably designed as a mobile system able to be removed from the oxygen reduction system (100) when needed.

2. The oxygen reduction system (100) according to claim 1,

which further comprises a compressor system (101) upstream of the gas separation system (102) for compressing an initial gas mixture to be fed to the gas separation system (102),

wherein the compressor system (101) upstream of the gas separation system (102) is preferably designed as a mobile system able to be removed from the oxygen reduction system (100) and/or the gas separation system (102) when needed; and/or

wherein a compressor system (103) is provided between the outlet of the gas separation system (102) and the inlet of the compressed gas storage (105; 105a-g) to compress as needed the oxygen-reduced gas mixture provided at the outlet of the gas separation system (102) and to be fed to the compressed gas storage (105; 105a-g),

wherein the compressor system (103) provided between the outlet of the gas separation system (102) and the inlet of the compressed gas storage (105; 105a-g) is preferably designed as a mobile system able to be removed from the oxygen reduction system (100) and/or the gas separation system (102) when needed.

3. The oxygen reduction system (100) according to claim 1 or 2, wherein a line system is provided by means of which the outlet of the gas separation system (102) is or can be selectively fluidly connected to an inlet of the compressed gas storage (105; 105a-g) and/or to the at least one enclosed area (107; 107a, 107b).
4. The oxygen reduction system (100) according to claim 3, wherein the line system, by means of which the outlet of the gas separation system (102) is or can be selectively fluidly connected to an inlet of the compressed gas storage (105; 105a-g) and/or to the at least one enclosed area (107; 107a, 107b), corresponds at least in part to the line system via which the compressed gas storage (105; 105a-g) is fluidly connected or connectable to the at least one enclosed area (107; 107a, 107b); and/or wherein the line system, by means of which the outlet of the gas separation system (102) is or can be selectively fluidly connected to an inlet of the compressed gas storage (105; 105a-g) and/or to the at least one enclosed area (107; 107a, 107b), can be configured at least in part as a mobile system able to be removed from the oxygen reduction system (100) and/or the gas separation system (102) when needed.

5. The oxygen reduction system (100) according to one of claims 1 to 4, further comprising a valve system having a first valve arrangement (104), wherein the first valve arrangement (104) is designed to form and/or cut off a fluidic connection between the outlet of the gas separation system (102) and the inlet of the compressed gas storage (105; 105a-g); and/or further comprising a valve system having a second valve arrangement (106; 106a-d), wherein the second valve arrangement (106; 106a-d) is designed to form and/or cut off a fluidic connection between an outlet of the compressed gas storage (105; 105a-g) and the at least one enclosed area (107; 107a, 107b); and/or further comprising a valve system having a third valve arrangement (109; 109a, 109b), wherein the third valve arrangement (109; 109a, 109b) is designed to form and/or cut off a fluidic connection between the outlet of the gas separation system (102) and the at least one enclosed area (107; 107a, 107b), wherein the valve system is preferably configured at least in part as a mobile system able to be removed from the oxygen reduction system (100) and/or the gas separation system (102) when needed.
6. The oxygen reduction system (100) according to one of claims 1 to 5, wherein the compressed gas storage (105; 105a-g) comprises at least one inlet and at least one outlet, wherein the inlet of the compressed gas storage (105; 105a-g) and the outlet of the compressed gas storage (105; 105a-g) are connected to the interior of the compressed gas storage (105; 105a-g) by a connector piece (113), wherein the connector piece (113) is preferably realized as a connector piece common to the at least one inlet and the at least one outlet; and/or wherein the connector piece (113) is preferably realized as a T-piece or Y-piece; and/or wherein the connector piece (113) is preferably formed in a container valve (108) of the compressed gas storage (105; 105a-g).
7. The oxygen reduction system (100) according to one of claims 1 to 6, which further comprises a control device (10) for the preferably coordinated actuating of controllable components of the oxygen reduction system (100), wherein the control device (10) is preferably designed to control a valve system of the oxygen reduction system (100) such that the outlet of the

gas separation system (102) is then preferably only fluidly connected to the inlet of the compressed gas storage (105; 105a-g) when there is no fluidic connection between the outlet of the compressed gas storage (105; 105a-g) and the at least one enclosed area (107; 107a, 107b) and/or no fluidic connection between the outlet of the gas separation system (102) and the at least one enclosed area (107; 107a, 107b).

8. The oxygen reduction system (100) according to one of claims 1 to 7, wherein the oxygen reduction system (100) comprises at least one pressure sensor (116) allocated to the compressed gas storage (105; 105a-g) for the as-needed or continuous detecting of a preferably static and/or dynamic gas pressure of the oxygen-reduced gas mixture or inert gas stored in the compressed gas storage (105; 105a-g); and/or wherein the oxygen reduction system (100) comprises at least one pressure sensor allocated to the at least one enclosed area (107; 107a, 107b) for the as-needed or continuous detecting of a preferably static gas pressure in the spatial atmosphere of the enclosed area (107; 107a, 107b); and/or wherein the oxygen reduction system (100) comprises at least one pressure sensor for detecting a preferably dynamic and/or static gas pressure at the inlet of the compressed gas storage (105; 105a-g), in particular when the gas mixture provided at the outlet of the gas separation system (102) is being fed to the compressed gas storage (105; 105a-g); and/or wherein the oxygen reduction system (100) comprises at least one temperature sensor (115) allocated to the compressed gas storage (105; 105a-g) for the as-needed or continuous detecting of a temperature of the oxygen-reduced gas mixture or inert gas stored in the compressed gas storage (105; 105a-g).
9. The oxygen reduction system (100) according to one of claims 1 to 8, wherein the oxygen reduction system (100) comprises at least one sensor (122) allocated to the gas separation system (102) for the as-needed or continuous detecting of a residual oxygen concentration in the oxygen-reduced gas mixture provided at the outlet of the gas separation system (102); and/or wherein the at least one gas separation system (102) has a first operating mode, in which an oxygen-reduced gas mixture is fed when required to the compressed gas storage (105; 105a-g), and a second operating mode, in which an oxygen-reduced gas mixture is fed when required to at least one

enclosed area (107; 107a, 107b), wherein the first and second operating mode can preferably be set by a control device (10) and even more preferentially automatically, in particularly selectively automatically, by a control device (10); and/or

wherein a compressor system (101) is arranged upstream of the at least one gas separation system (102), wherein the upstream compressor system (101) has a first operating mode, in which an oxygen-reduced gas mixture is fed when required to the compressed gas storage (105; 105a-g), and a second operating mode, in which an oxygen-reduced gas mixture is fed when required to at least one enclosed area (107; 107a, 107b), wherein the first and second operating mode can preferably be set by a control device (10) and even more preferentially automatically, in particularly selectively automatically, by a control device (10); and/or wherein the outlet of the gas separation system (102) is connected or connectable to a first collecting line (110) via a valve (104),

wherein the first collecting line (110) and/or the valve (104) is/are preferably designed as a mobile system able to be removed from the oxygen reduction system (100) and/or the gas separation system (102) when needed.

10. The oxygen reduction system (100) according to one of claims 1 to 9, wherein the compressed gas storage (105) comprises a plurality of spatially separated compressed gas containers (105a-g) connected together in parallel which have at least one, preferably one respective container valve (108) in each case.
11. The oxygen reduction system (100) according to claim 10, wherein a first line section is provided for preferably each of the plurality of compressed gas containers (105a-g) via which the respective container valve (108) of the compressed gas container (105a-g) is fluidly connected to a first collecting line (110); and/or wherein the container valve (108) of preferably each of the plurality of compressed gas containers (105a-g) is fluidly connected in each case to a second collecting line (111) via a second line section (111), wherein the second collecting line (111) is fluidly connected or connectable to the at least one enclosed area (107; 107a, 107b) preferably via a valve (106, 106a-d), in particular an area valve, and

wherein the second collecting line (111) and/or the valve (106, 106a-d) is/are preferably designed as a mobile system able to be removed from the oxygen reduction system (100) and/or the gas separation system (102) when needed.

12. The oxygen reduction system (100) according to one of claims 1 to 11, wherein a control device (10) is provided which is designed to preferably automatically, and even more preferentially, selectively automatically actuate the valve arrangements (104, 106, 109) allocated to the oxygen reduction system (100) in coordinated manner such that the outlet of the at least one gas separation system (102) can be fluidly connected to the inlet of at least one compressed gas container (105a-g) when there is a fluidic connection between the outlet of at least one further compressed gas container (105a-g) and the at least one enclosed area (107; 107a, 107b); and/or
 wherein a control device (10) is provided which is designed to preferably automatically, and even more preferentially, selectively automatically actuate the valve arrangements (104, 106, 109) allocated to the oxygen reduction system (100) in coordinated manner so as to selectively establish a fluidic connection between the inlet of the least one compressed gas container (105a-g) and the outlet of the gas separation system (102) upon the detecting of a predetermined or determinable minimum pressure and/or upon at least one of the compressed gas containers (105a-g) falling below a predetermined or determinable minimum pressure; and/or
 wherein a backflow preventer (112), in particular designed as a check valve, is allocated to at least one compressed gas container (105a-g) to block a flow of gas to the compressed gas container (105a-g) from a line system running between the compressed gas container (105a-g) and the enclosed area (107; 107a, 107b); and/or
 wherein a backflow preventer (112), in particular designed as a check valve, is allocated to at least one compressed gas container (105a-g) to block a flow of gas from the compressed gas container (105a-g) to a line system running between the outlet of the at least one gas separation system (102) and the compressed gas container (105a-g); and/or
 wherein at least one of the plurality of compressed gas containers (105a-g) comprises a container valve (108) having a preferably pneumatically actuatable quick release valve arrangement for the as-needed establishing of a fluidic connection between the respective compressed gas container

(105a-g) and a line system running between the compressed gas container (105a-g) and the enclosed area (107; 107a, 107b)

wherein the valve function of the quick release valve arrangement can preferably be switched off when required, particularly when the outlet of the gas separation system (102) is or is to be connected to the inlet of the compressed gas container (105a-g).

13. The oxygen reduction system (100) according to one of claims 1 to 12, wherein the gas separation system (102) comprises a first gas separator, preferably in the form of a nitrogen generator, and at least one further second gas separator, preferably in the form of a nitrogen generator.
14. The oxygen reduction system (100) according to claim 13, wherein the first gas separator is realized as a gas separator intended to be stationary, and wherein the at least one second gas separator is realized as a mobile gas separator; or wherein the first and the at least one second gas separator are each realized as gas separators intended to be stationary; or wherein the first and the at least one second gas separator are each realized as mobile gas separators.
15. The oxygen reduction system (100) according to one of claims 1 to 14, wherein a sensor device is provided for monitoring the residual oxygen content of the oxygen-reduced gas mixture provided at the outlet of the gas separation system (102), wherein a control device (10) is preferably provided which is designed to only feed the oxygen-reduced gas mixture provided at the outlet of the gas separation system (102) to the compressed gas storage (105; 105a-g) when the residual oxygen content of the oxygen-reduced gas mixture provided at the outlet of the gas separation system (102) does not exceed a predefined or definable threshold.
16. The oxygen reduction system (100) according to one of claims 1 to 15, wherein the nitrogen concentration of the oxygen-reduced gas mixture provided at the outlet of the gas separation system (102) can be switched between at least two predefined or definable values, wherein the gas separation system (102) is preferably designed to provide an oxygen-reduced gas mixture of a first nitrogen concentration at the

outlet of the gas separation system (102) when the oxygen-reduced gas mixture provided at the outlet of the gas separation system (102) is to be fed to the at least one enclosed area (107; 107a, 107b), and to provide an oxygen-reduced gas mixture of a second nitrogen concentration at the outlet of the gas separation system (102) when the oxygen-reduced gas mixture provided at the outlet of the gas separation system (102) is to be fed to the compressed gas storage (105; 105a-g), wherein the first nitrogen concentration is preferably lower than the second nitrogen concentration, and/or wherein the second nitrogen concentration is preferably at least 99% by volume.

17. A method for operating an oxygen reduction system (100), in particular an oxygen reduction system (100) according to one of claims 1 to 16, wherein the method comprises the following method steps:

- i) storing an oxygen-reduced gas mixture or inert gas in compressed form in a compressed gas storage (105; 105a-g);
- ii) feeding at least some of the gas mixture or inert gas stored in compressed form in the compressed gas storage (105; 105a-g) to the enclosed area (107; 107a, 107b) to rapidly reduce the oxygen content in the spatial atmosphere of an enclosed area (107; 107a, 107b), and that by the compressed gas storage (105; 105a-g) being fluidly connected to the enclosed area (107; 107a, 107b);
- iii) feeding an oxygen-reduced gas mixture provided at an outlet of a gas separation system (102) to the enclosed area (107; 107a, 107b) in regulated manner in order to maintain a reduced oxygen content and/or to reduce the oxygen content in the spatial atmosphere of an enclosed area (107; 107a, 107b), and that by the outlet of the gas separation system (102) being fluidly connected to the enclosed area (107; 107a, 107b);

wherein an at least partial refilling of the compressed gas storage (105; 105a-g) or a refilling of at least one compressed gas container (105a-g) of the compressed gas storage (105) occurs subsequent to method step ii) and preferably parallel to method step iii), and that by the outlet of the gas separation system (102) or the least one compressed gas container (105a-g) of the compressed gas storage (105) respectively being fluidly connected to the compressed gas storage (105; 105a-g); and

wherein the providing of the oxygen-reduced gas mixture at the outlet of the gas separation system (102), the feeding of the oxygen-reduced gas mixture provided at the outlet of the gas separation system (102) to the compressed gas storage (105; 105a-g), the feeding of the oxygen-reduced gas mixture provided at the outlet of the gas separation system (102) to the at least one enclosed area (107; 107a, 107b), and/or the feeding of the oxygen-reduced gas mixture/inert gas stored in the compressed gas storage (105; 105a-g) to the at least one enclosed area (107; 107a, 107b) is coordinated with the help of a sensor unit (114).

18. The method according to claim 17,
 - wherein at least a portion of the gas mixture or inert gas stored in compressed form in the compressed gas storage (105; 105a-g) is fed to the enclosed area (107; 107a, 107b) in method step ii) such that the oxygen concentration in the enclosed area (107; 107a, 107b) does not fall below a predefined or definable first value subject in particular to a fire load of the enclosed area (107; 107a, 107b) and does not exceed a likewise predefined or definable second value, wherein the second value is preferably less than the value of the oxygen concentration in the normal atmosphere and preferably greater than the first value;
 - wherein the oxygen-reduced gas mixture provided at the outlet of the gas separation system (102) is preferably fed to the enclosed area (107; 107a, 107b) in method step iii) in regulated manner such that the oxygen concentration in the enclosed area (107; 107a, 107b) does not fall below the first predefined or definable value and does not exceed the second predefined or definable value; and/or
 - wherein the first and second predefined or definable values preferably correspond to lower and upper limit values of a base inerted level of the enclosed area (107; 107a, 107b); and/or
 - wherein the oxygen-reduced gas mixture provided at the outlet of the gas separation system (102) is only fed to the enclosed area (107; 107a, 107b) in regulated manner in method step iii) when it has been preferably automatically verified, in particular by means of at least one fire detector, or manually verified, in particular by actuating a corresponding switch, that no fire is present within the enclosed area (107; 107a, 107b) during or after the rapid lowering of the oxygen content in the spatial atmosphere of the enclosed area (107; 107a, 107b) in method step ii).

19. The method according to claim 17 or 18, wherein it is automatically verified, in particular by means of at least one fire detector, or manually verified, in particular by actuating a corresponding switch, that a fire which had broken out in the enclosed area (107; 107a; 107b) has not been or not sufficiently suppressed subsequent the rapid lowering of the oxygen content in the spatial atmosphere of the enclosed area (107; 107a; 107b), and wherein the method further comprises the following method step subsequent to method step iii):

- iv) further reducing the oxygen content in the spatial atmosphere of the enclosed area (107; 107a; 107b), and that by feeding at least a portion of the gas mixture or inert gas stored in compressed form in the compressed gas storage (105; 105a-g) to the enclosed area (107; 107a, 107b), and that by the compressed gas storage (105; 105a-g) or at least one compressed gas container (105a-g) of the compressed gas storage (105) being fluidly connected to the enclosed area (107; 107a, 107b),

wherein the oxygen content in the spatial atmosphere of the enclosed area (107; 107a; 107b) preferably continues to be further reduced in method step iv) until the oxygen concentration in the enclosed area (107; 107a; 107b) reaches a predefined or definable target concentration which corresponds to a nitrogen concentration at least as equally high as an extinguishing gas concentration dependent on the fire load of the enclosed room,

wherein the predefined or definable target oxygen concentration in the enclosed area (107; 107a; 107b) preferably corresponds to a fully inerted level,

wherein the following method step is preferably provided subsequent method step iv):

- v) maintaining the predefined or definable target oxygen concentration in the enclosed area (107; 107a; 107b), and doing so by feeding an oxygen-reduced gas mixture provided at the outlet of the gas separation system (102) to the enclosed area (107; 107a, 107b) in regulated manner, and that by the outlet of the gas separation system (102) being fluidly connected to the enclosed area (107; 107a, 107b),

wherein at least a partial refilling of the compressed gas storage (105; 105a-g) or a refilling of at least one compressed gas container (105a-g) of the compressed gas storage (105) preferably occurs subsequent to method step iv) and preferably parallel to method step v), and that by the inlet of the gas separation system (102) being fluidly connected to the compressed gas storage (105; 105a-g) or to the at least one compressed gas container (105a-g) of the compressed gas storage (105) respectively.

20. The method according to one of claims 17 to 19, wherein the enclosed area (107; 107a; 107b) is preferably continuously monitored or monitored at predefined times/events with regard to the presence of at least one fire characteristic, and wherein at least method step ii) is preferably automatically initiated as soon as at least one fire characteristic is detected.