



(12) **DEMANDE DE BREVET CANADIEN**
CANADIAN PATENT APPLICATION

(13) **A1**

(86) Date de dépôt PCT/PCT Filing Date: 2020/08/25

(87) Date publication PCT/PCT Publication Date: 2021/04/01

(85) Entrée phase nationale/National Entry: 2022/02/03

(86) N° demande PCT/PCT Application No.: EP 2020/073748

(87) N° publication PCT/PCT Publication No.: 2021/058217

(30) Priorité/Priority: 2019/09/25 (NO20191157)

(51) Cl.Int./Int.Cl. *B65G 1/04* (2006.01)

(71) Demandeur/Applicant:
AUTOSTORE TECHNOLOGY AS, NO

(72) Inventeurs/Inventors:
FJELDHEIM, IVAR, NO;
AUSTRHEIM, TROND, NO

(74) Agent: BERESKIN & PARR LLP/S.E.N.C.R.L.,S.R.L.

(54) Titre : SYSTEME DE STOCKAGE ISOLE AU GAZ

(54) Title: GAS ISOLATED STORAGE SYSTEM

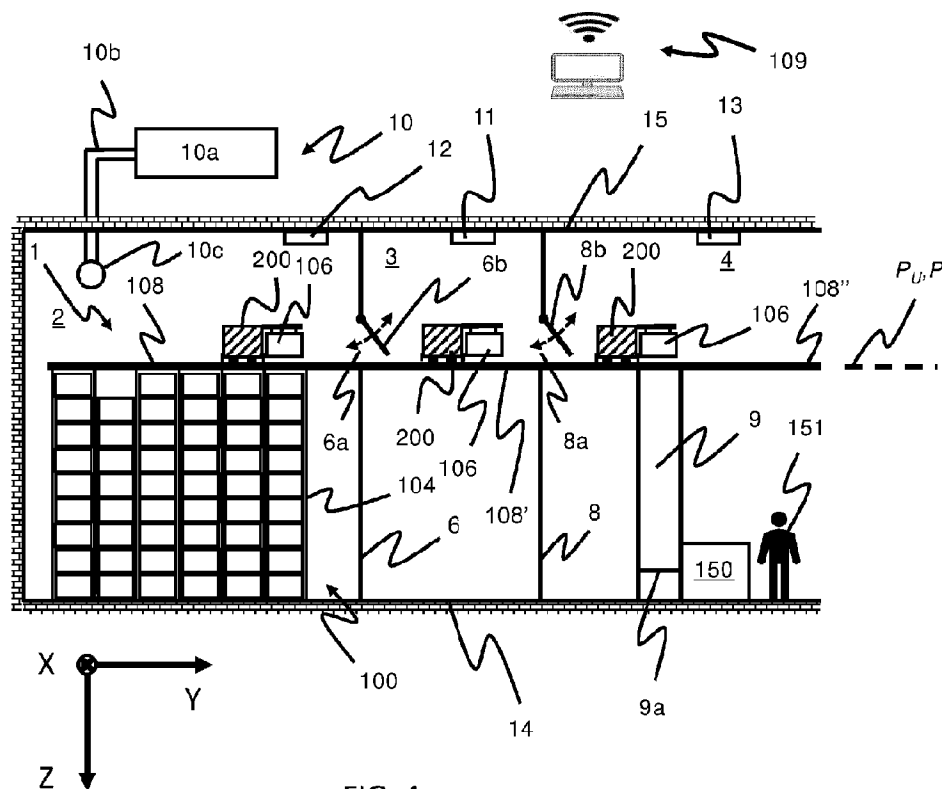


FIG. 4

(57) Abrégé/Abstract:

The invention concerns a storage facility comprising a gas isolated storage space containing an automated storage and retrieval system and a method for using such a storage facility.

(19) World Intellectual Property

Organization

International Bureau

(43) International Publication Date

01 April 2021 (01.04.2021)



(10) International Publication Number

WO 2021/058217 A3



(51) International Patent Classification:

B65G 1/04 (2006.01)

(21) International Application Number:

PCT/EP2020/073748

(22) International Filing Date:

25 August 2020 (25.08.2020)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

20191157

25 September 2019 (25.09.2019) NO

(71) Applicant: AUTOSTORE TECHNOLOGY AS

[NO/NO]: Stokkastrandvegen 85, 5578 Nedre Vats (NO).

(72) **Inventors: FJELDHEIM, Ivar**; Bjørnebærveien 9, 5533

HAUGESUND (NO). AUSTRHEIM, Trond; Nedre
Teigen 12, 5590 Etne (NO).

(74) **Agent: ONSAGERS AS**; P. O. Box 1813 Vika, 0123 Oslo (NO).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ,

CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO,
DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN,
HR, HU, ID, IL, IN, IR, IS, IT, JO, JP, KE, KG, KH, KN,
KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD,
ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO,
NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW,
SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN,
TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

- *as to the identity of the inventor (Rule 4.17(i))*
- *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*
- *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*
- *of inventorship (Rule 4.17(iv))*

(54) Title: GAS ISOLATED STORAGE SYSTEM

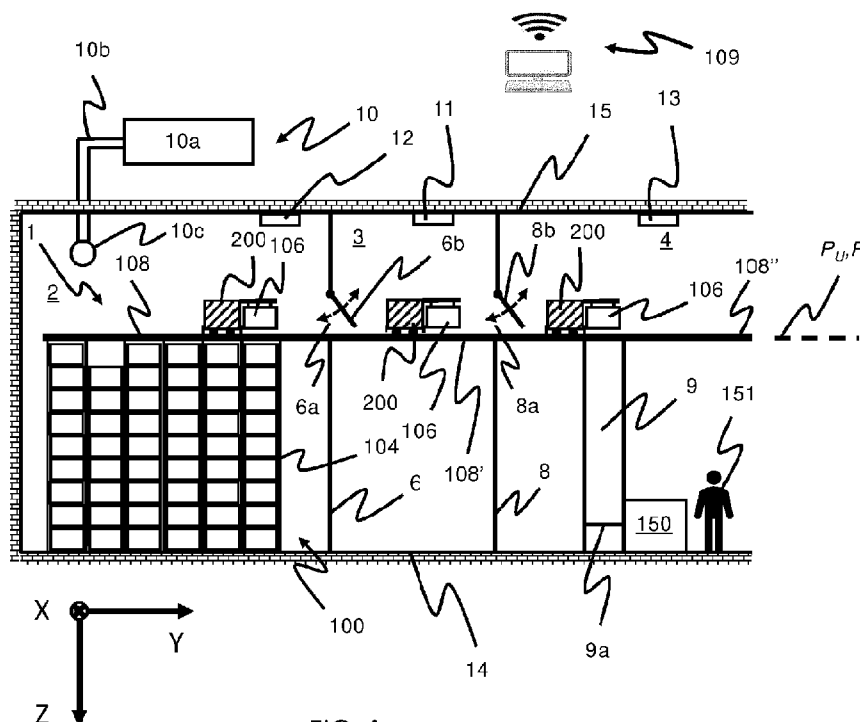


FIG. 4

(57) Abstract: The invention concerns a storage facility comprising a gas isolated storage space containing an automated storage and retrieval system and a method for using such a storage facility.

[Continued on next page]

WO 2021/058217 A3

WO 2021/058217 A3

Published:

- *with international search report (Art. 21(3))*
- *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

(88) Date of publication of the international search report:

14 May 2021 (14.05.2021)

GAS ISOLATED STORAGE SYSTEM

TECHNICAL FIELD

The present invention relates to a facility and a method for gas isolating an automated storage and retrieval system.

5 BACKGROUND AND PRIOR ART

Fig. 1A discloses a typical prior art automated storage and retrieval system 1 with a framework structure 100.

10 The framework structure 100 comprises a plurality of upright members 102 and optionally a plurality of horizontal members 103 supporting the upright members 102. The members 102, 103 may typically be made of metal, e.g. extruded aluminum profiles.

The framework structure 100 defines a storage grid 104 comprising storage columns 105 arranged in rows, in which storage columns 105 storage containers 106 (also known as bins) are stacked one on top of another to form stacks 107.

15 Each storage container 106 may typically hold a plurality of product items (not shown), and the product items within a storage container 106 may be identical or may be of different product types depending on the application.

20 The storage grid 104 guards against horizontal movement of the storage containers 106 in the stacks 107, and guides vertical movement of the storage containers 106, but normally does not otherwise support the storage containers 106 when stacked.

25 The automated storage and retrieval system 1 comprises a rail system 108 arranged in a grid pattern across the top of the storage grid 104, on which rail system 108 a plurality of container handling vehicles 200 (as exemplified in Fig. 1C) are operated to raise storage containers 106 from, and lower storage containers 106 into, the storage columns 105, and also to transport the storage containers 106 above the storage columns 105. The horizontal extent of one of the grid cells 122 constituting the grid pattern is marked by thick lines in Fig. 1A.

30 The rail system 108 comprises a first set of parallel rails 110 arranged to guide movement of the container handling vehicles 200 in a first direction X across the top of the frame structure 100, and a second set of parallel rails 111 arranged perpendicular to the first set of parallel rails 110 to guide movement of the container handling vehicles 200 in a second direction Y which is perpendicular to the first direction X . In this way, the rail system 108 defines grid columns above which the container handling vehicles 200 can move laterally above the storage
35 columns 105, i.e. in a plane which is parallel to the horizontal X - Y plane.

The rail system 108 may be a single rail system or a double rail system as is shown in Fig. 1B. The latter rail configuration allows a container handling vehicle 200 having a footprint generally corresponding to the lateral area defined by a grid cell 122 in at least one of the X and Y directions to travel along a row of grid columns even if another container handling vehicle 200 is positioned above a grid cell neighboring that row. Both the single and double rail system, or a combination comprising a single and double rail arrangement in a single rail system 108, form a grid pattern in the horizontal plane P comprising a plurality of rectangular and uniform grid locations or grid cells 122, where each grid cell 122 comprises a grid opening 115 being delimited by a pair of neighboring rails 110a, 110b of the first set of parallel rails 110 and a pair of neighboring rails 111a, 111b of the second set of parallel rails 111.

Consequently, rails 110a and 110b form pairs of rails defining parallel rows of grid cells running in the X direction, and rails 111a and 111b form pairs of rails defining parallel rows of grid cells running in the Y direction.

As shown in Fig. 1B, each grid cell 122 (indicated by a dashed box) has a width W_c which is typically within the interval of 30 to 150 cm, and a length L_c which is typically within the interval of 50 to 200 cm. Each grid opening 115 has a width W_o which is typically 2 to 10 cm less than the width W_c of the grid cell 122. Each grid opening 115 has a length L_o which is typically 2 to 10 cm less than the length L_c of the grid cell 122.

Fig. 1C discloses a prior art container handling vehicle 200 operating the system 1 disclosed in Figs. 1A. Each prior art container handling vehicle 200 comprises a vehicle body 202 and a wheel arrangement 201 of eight wheels, where a first set of four wheels enable the lateral movement of the container handling vehicles 200 in the X direction and a second set of the remaining four wheels enable the lateral movement in the Y direction. One or both sets of wheels in the wheel arrangement 201 can be lifted and lowered, so that the first set of wheels and/or the second set of wheels can be engaged with the respective set of rails 110, 111 at any one time.

Each prior art container handling vehicle 200 also comprises a lifting device 203 for vertical transportation of storage containers 106, e.g. raising a storage container 106 from, and lowering a storage container 106 into, a storage column 105. The lifting device 203 may comprise one or more gripping / engaging devices which are adapted to engage a storage container 106, and which gripping / engaging devices can be lowered from the vehicle 200 so that the position of the gripping / engaging devices with respect to the vehicle can be adjusted in a third direction Z which is orthogonal to the first direction X and the second direction Y .

Conventionally, and also for the purpose of this application, $Z=1$ identifies the uppermost layer of the grid 104, i.e. the layer immediately below the rail system 108, $Z=2$ identifies the second layer below the rail system 108, $Z=3$ identifies the third layer etc. In the exemplary prior art grid 104 disclosed in Fig. 1A, $Z=8$ identifies the lowermost, bottom layer of the grid 104. Consequently, as an example, and using the Cartesian coordinate system X, Y, Z indicated in Fig. 1A, the storage container identified as 106' in Fig. 1A can be said to occupy grid location or cell $X=10, Y=2, Z=3$. The container handling vehicles 200 can be said to travel in layer $Z=0$ and each grid column can be identified by its X and Y coordinates.

Each container handling vehicle 200 comprises a storage compartment or space (not shown) for receiving and stowing a storage container 106 when transporting the storage container 106 across the rail system 108.

The container handling vehicles 200 may have a cantilever construction, as is described in NO317366, the contents of which are also incorporated herein by reference.

Alternatively, the container handling vehicles may have a footprint, i.e. an extent in the X and Y directions, which is generally equal to the lateral extent of a grid cell 122, i.e. the extent of a grid cell 122 in both the X and Y directions, e.g. as is described in WO2015/193278A1, the contents of which are incorporated herein by reference.

The term "lateral" used herein may mean "horizontal".

In the X and Y directions, neighboring grid cells are arranged in contact with each other such that there is no space there-between.

In a storage grid 104, a majority of the grid columns are storage columns 105, i.e. grid columns 105 where storage containers 106 are stored in stacks 107. However, a grid 104 normally has at least one grid column which is used not for storing storage containers 106, but which comprises a location where the container handling vehicles 200 can drop off and/or pick up storage containers 106 so that they can be transported to a second location (not shown) where the storage containers 106 can be accessed from outside of the grid 104 or transferred out of or into the grid 104. Within the art, such a location is normally referred to as a "port" and the grid column in which the port is located may be referred to as a "delivery column" 119, 120. The drop-off and pick-up ports where the container handling vehicles 200 delivers and receives containers 106, respectively, are referred to as the "upper ports of a delivery column" 119, 120, while the opposite end of the delivery column is referred to as the "lower ports of a delivery column".

The storage grid 104 in Fig. 1A comprises two delivery columns 119 and 120. The first delivery column 119 may for example comprise a dedicated drop-off port where the container handling vehicles 200 can drop off storage containers 106 to be transported through the delivery column 119 and further to an access station or a transfer station, and the second delivery column 120 may comprise a dedicated pick-up port where the container handling vehicles 200 can pick up storage containers 106 that have been transported through the delivery column 120 from an access station or a transfer station. Each of the ports of the first and second delivery column 119, 120 may comprise a port suitable for both pick up and drop off of storage containers 106.

The second location may typically be a picking station or a stocking station where product items are removed from or positioned into the storage containers 106. In a picking station or a stocking station, the storage containers 106 are normally never removed from the automated storage and retrieval system 1 but are returned into the storage grid 104 once accessed. For transfer of storage containers out of or into the storage grid 104, there are also lower ports provided in a delivery column, such lower ports are e.g. for transferring storage containers 106 to another storage facility (e.g. to another storage grid), directly to a transport vehicle (e.g. a train or a lorry), or to a production facility.

A conveyor system may also be arranged to transfer storage containers between different storage grids, e.g. as is described in WO2014/075937A1, the contents of which are incorporated herein by reference.

When a storage container 106 stored in the storage grid 104 disclosed in Fig. 1A is to be accessed, one of the container handling vehicles 200 is instructed to retrieve the target storage container 106 from its position in the grid 104 and transport it to or through the delivery column 119. This operation involves moving the container handling vehicle 200 to a grid location above the storage column 105 in which the target storage container 106 is positioned, retrieving the storage container 106 from the storage column 105 using the container handling vehicle's lifting device 203, and transporting the storage container 106 to the delivery column 119. If the target storage container 106 is located deep within a stack 107, i.e. with one or a plurality of other storage containers positioned above the target storage container 106, the operation also involves temporarily moving the above-positioned storage containers prior to lifting the target storage container 106 from the storage column 105. This step, which is sometimes referred to as "digging" within the art, may be performed with the same container handling vehicle 200 that is subsequently used for transporting the target storage container 106 to the delivery column 119, or with one or a plurality of other cooperating container handling vehicles 200. Alternatively, or in addition, the automated storage and retrieval system 1 may have container handling vehicles specifically dedicated to the task of temporarily removing storage containers 106 from a storage column 105. Once the target storage container 106 has been removed from

the storage column 105, the temporarily removed storage containers can be repositioned into the original storage column 105. However, the removed storage containers may alternatively be relocated to other storage columns 105.

5 When a storage container 106 is to be stored in the grid 104, one of the container handling vehicles 200 is instructed to pick up the storage container 106 from the second delivery column 120 and to transport it to a grid location above the storage column 105 where it is to be stored. After any storage containers positioned at or above the target position within the storage column stack 107 have been removed, the container handling vehicle 200 positions the storage container 106 at the desired position. The removed storage containers may then be lowered back into the storage column 105 or relocated to other storage columns 105.

15 For monitoring and controlling the automated storage and retrieval system 1 so that a desired storage container 106 can be delivered to the desired location at the desired time without the container handling vehicles 200 colliding with each other, the automated storage and retrieval system 1 comprises a control system 109, which typically is computerized and comprises a database for monitoring and controlling e.g. the location of the respective storage containers 106 within the storage grid 104, the content of each storage container 106 and the movement of the container handling vehicles 200.

20 The storage systems of the type described above are housed in storage facilities together with other equipment like ports and charging stations (for charging the container handling vehicles 200). Other areas linked to the operation of the storage systems such as maintenance areas and control rooms are often open towards the rail systems on which the container handling vehicles 200 and the charging stations are operating.

Some recent storage systems such as the automated storage and retrieval system developed by the company Autostore AS are equipped with movable physical barriers between the rail systems and said other areas that can be raised and lowered when needed.

30 However, in the event that a fire starts within the storage system, there is a significant risk that the fire would spread to other parts of the facility, for example to areas where human workers are working. Movable physical barriers such as those found in the storage systems of Autostore AS may to a certain degree slow down the spread of the fire. But such measures are not able to reduce the risk of a fire breaking out and/or spreading to zero or near zero.

35 Some prior art systems, such as the storage system of Autostore AS, incorporate measures to both detect and extinguish fire through a set of sensors and fire extinguishers.

A problem associated with most known automated storage and retrieval systems is that they do not have means to prevent fires from starting, only means to extinguish an existing fire. And it is difficult to avoid any flammable material within a commercial storage facility.

- 5 For a fire to start at least three elements need to be present: heat, fuel and oxygen. Heat is usually in the form of a high surface temperature and/or a spark. Fuel may be any material that is flammable, e.g. wood. And finally, oxygen is needed in order to keep combustion going.

If one of these three elements are missing it is unlikely that a fire will ignite.

- 10 Even if precautionary measures are taken in order to prevent surface temperatures from becoming too high and/or to prevent sparks from forming, the risk in an automated storage and retrieval system can never be reduced to zero since container handling vehicles operating on the rail system of the above-mentioned storage system are operated with high electric power and high acceleration. The latter
15 criteria may for example create friction that may ignite a fire on debris on the rail system. Further, the charging stations may create sparks or create high temperatures that can cause a fire to start.

- It is however possible to control or maintain a non-flammable, or near non-flammable, atmosphere inside the storage facility and thereby reduce the risk of fire
20 significantly. Oxygen concentration in the atmosphere at sea level is around 21% per volume. This concentration of oxygen is sufficiently high to allow fire to ignite. At lower oxygen concentrations (for example, below 16%), the risk of ignition is greatly reduced.

- Such a storage facility where the oxygen concentration is reduced in order to
25 prevent start of fire is described in the article “WagnerImpulse” in the magazine “The Wagner Group Customer magazine” (3/2018). The low oxygen concentration is obtained by forcing oxygen-reduced air into the entire storage facility.

- However, exchanging the air of the entire storage facility is both time consuming and energy consuming. Furthermore, such a solution hinders humans working inside
30 the storage facility. Humans may work in areas down to about 13% by volume of oxygen. But with such a low oxygen content, the workers need breaks of at least 30 minutes after 2 hours working.

- Moreover, the article does not present any solutions for maintaining such a low oxygen concentration over a long time span such as several days. For example, the
35 article gives no indication of how the storage system may be operated to transport bins in or out of the storage system without increasing the oxygen concentration.

Such an operation would necessitate frequent exposure of the storage system to atmospheric air.

It is therefore an aim of the present invention to provide an automated storage and retrieval system and a method for operating such a system that solves or at least mitigates one or more of the aforementioned problems related to the use of prior art storage and retrieval systems.

A particular object of the invention is to provide solution(s) that allows handling of containers within a storage system located in a space having an environment different than the surrounding environment.

For one or more embodiments of the invention, another object is to provide solution(s) that significantly reduces the risk of a fire starting within or on the storage system during operation and which does not reduce the operational efficiency significantly compared to the prior art storage systems as described above.

For one or more embodiments of the invention, yet another object is to provide solution(s) that may control physical characteristics of the environment in which the storage system is arranged.

For one or more embodiments of the invention, yet another object is to provide solution(s) that may distinguish an existing fire within and/or in the vicinity of the storage system.

For one or more embodiments of the invention, yet another object of the invention is to provide solution(s) that allows safe long-term storage of biological species and/or fresh food.

Summary of the invention:

The present invention is set forth and characterized in the independent claims, while the dependent claims describe other optional/preferred features.

In a first aspect, the invention concerns a storage facility for gas isolating an automated storage and retrieval system.

In one or more embodiments within the first aspect, the invention concerns a storage facility for controlling a gas concentration in an automated storage and retrieval system.

The storage facility comprises a storage space enclosing a storage and retrieval system comprising a storage grid configured to store a plurality of storage containers in vertical stacks and a first upper vehicle support such as a rail system extending in an upper horizontal plane (P_U) above the storage grid, i.e. in a plane directed perpendicular to the vertical stacks.

5 The system further comprises a container handling vehicle configured to transport at least one of the plurality of storage containers by means of a wheel arrangement between at least two locations on the first upper vehicle support and to vertically displace the at least one storage container by means of a lifting device capable of lifting and lowering the at least one storage container.

10 The system further comprises a first lower vehicle support such as a rail system extending in a lower horizontal plane (P_L) below the first upper vehicle support and a container delivery vehicle operating within a lower section of the storage space above the first lower vehicle support. The container delivery vehicle is configured to receive the at least one storage container from the container handling vehicle and to transport the at least one storage container between at least two locations on the first lower vehicle support by means of a wheel arrangement.

15 The system further comprises a transit space comprising a second lower vehicle support such as a rail system extending in the lower horizontal plane P_L and arranged relative to the first lower vehicle support such that the container delivery vehicle may move between the lower section of the storage space and a lower section of the transit space, and a first separation wall separating the storage space and the transit space.

20 The first separation wall comprises a first lower opening sized and positioned to allow the container delivery vehicle to pass through between the lower section of the storage space and the lower section of the transit space and a first lower closable gate configured to open and close the first lower opening.

25 The enclosure of the storage space and the transit space may comprise four vertical walls, one base and one ceiling. However, other confinement configurations may be envisaged.

Note that the term 'gas isolation' is hereinafter defined as a closed space having an insignificant leakage of gas during typical operational time periods, for example more than 4 hours. Insignificant leakage may for example be a leakage of less than 5 % during a 4 hours period of operation.

30 The system may further comprise a gas regulating device in fluid communication with the storage space.

35 The gas regulating device may be configured to regulate a gas composition of a gas within the storage space before and/or during operation, such as lowering and/or raising a first gas concentration, such as the O_2 concentration. If desired, the pressure may be kept constant by injecting / extracting another gas during or after lowering / raising the first mentioned gas concentration. In the same way, the pressure may be raised or lowered to another predetermined level. For example,

lowering the O₂ concentration to 10 % may be accompanied by correspondingly raising the N₂ concentration in order to maintain a pressure within the storage space of 1 atmosphere (approximately 101 kPa). There exist situations where also oxygen-enriched air may prove beneficial, for example during storage and/or treatment of certain biological samples / food articles.

Alternatively, or in addition, to the gas regulating device, the system may comprise a fire extinguishing system or device configured to inject fire extinguishing substances into the storage space to distinguish a fire there within. At least one of the fire extinguishing substances may be a gas comprising at least one of Argonite IG-55 (inert gas comprising 50 % Argon and 50 % Nitrogen), CO₂, heptafluoropropane (also called HFC-227ea), N₂ and pressurized water. The fire extinguishing device may be arranged in any position that ensures the fire extinguishing substances to be spread into the storage space. The fire extinguishing device may for example be arranged within the storage space and/or at least partly within one or more of the walls enclosing the storage space and/or outside the storage space. The latter arrangement may be implemented by allowing the fire extinguishing substances to flow from the fire extinguishing device into the storage space via one or more fluid/gas inlets.

The fire extinguishing device may further comprise means to distribute the fire extinguishing substances homogeneously, or near homogeneously, within the storage space and/or means to target the fire extinguishing substances to specific locations / areas within the storage space. As an example only, the means may comprise a plurality of nozzles directed towards storage columns of the storage facility and/or to any operational space for container handling vehicles operating on top of storage columns and/or positions of charging stations.

The system may alternatively, or in addition, comprise a cooling facility configured to cool down the storage space to a temperature below an ambient temperature, for example to a temperature at or below 10°C, more preferably at or below 5°C, for example 2°C. As for the exemplary configuration with the fire extinguishing device, the cooling facility may be arranged in any position that ensures the desired cooling within the storage space. The cooling facility may for example be arranged within the storage space and/or at least partly within one or more of the walls enclosing the storage space and/or outside the storage space. The latter arrangement may be implemented by letting the cooled fluids to flow from the cooling facility into the storage space via one or more fluid/gas inlets.

The cooling facility may for example comprise refrigeration circuits and/or condensing units.

As noted above, the system further comprises a transit space comprising a second lower vehicle support extending in the lower horizontal plane P_L and arranged

relative to the first lower vehicle support such that the container delivery vehicle may move between the lower section of the storage space and a lower section of the transit space, and a first separation wall separating the storage space and the transit space. The container delivery vehicle may move between the lower section of the storage space and a lower section of the transit space without any need of external intervention. The arrangement of the second lower vehicle support relative to the first lower vehicle support may be performed by aligning the vehicle support adjacent to each other or adding a link which bridges the two vehicle supports, or a combination thereof. The two vehicle supports may also be integrated into each other, thereby constituting one continuous support.

As also set out above, the first separation wall comprises a first lower opening sized and positioned to allow the container delivery vehicle to pass through between the lower section of the storage space and the lower section of the transit space and a first lower closable gate configured to open and close the first lower opening. The first lower opening may for example have a size corresponding to at least the width of two side-by-side positioned container handling vehicles, for example the width of three.

The external boundaries confining the storage space and the transit space is preferably airtight, or near airtight, with the exception of the closable gate(s) when in open position(s).

The first lower closable gate may be configured to be remotely opened and closed by use of a remote control system, for example by the same control system used for controlling the operation of the container handling vehicles and/or the container handling vehicles.

The first lower closable gate may be further configured to create a fluid-tight seal between the storage space and the transit space when the first lower closable gate closes the first lower opening, for example by use of rubber gaskets. Such rubber gaskets may surround the outer periphery of the first upper closable gate, and/or the inner periphery of the first upper opening.

The storage facility may further comprise a handling space suitable for handling storage containers transported from or to the storage and retrieval system within the storage space and a second separation wall separating, preferably in a fluid-tight manner, the handling space and the transit space. Fluid is herein defined as including substances such as gas, vapor, etc.

The second separation wall comprises in the exemplary embodiment a second lower opening sized and positioned to allow the container delivery vehicle to pass through between the lower section of the transit space and a lower section of the handling space and a second lower closable gate configured to open and close the second

lower opening. The second lower opening may have a size corresponding to at least the width of two side-by-side positioned container handling vehicles, for example the width of three. Further, the second lower closable gate is preferably configured to be remotely operated from a remote control system, for example the control
5 system used to operate the container handling vehicles and/or the container handling vehicles.

The handling space may comprise a third lower vehicle support such as a rail system extending in the lower horizontal plane P_L . The third lower vehicle support may be arranged relative to the second lower vehicle support in the same way as for
10 the first and second lower vehicle supports, i.e. such that the container delivery vehicle may move between the second lower vehicle support and the third lower vehicle support through the second lower opening between the lower section of the transit space and the lower section of the handling space, preferably without any need of external intervention. As described above, this may be achieved by aligning
15 the vehicle support adjacent to each other or adding a link which bridges the two vehicle supports, or a combination thereof. The second and third vehicle supports may also be integrated into each other, thereby constituting one continuous support.

The handling space may further comprise a container delivery station configured to receive a storage container transferred by the container delivery vehicle for further
20 handling, or to deliver a storage container to the container delivery vehicle for storing the storage container into the storage and retrieval system or a combination thereof.

The container delivery station is preferably arranged at a vertical position different from the upper horizontal plane P_U , for example at or near the lower horizontal
25 plane P_L .

The container delivery vehicle may move along the third lower vehicle support from the second lower opening to a location adjacent to the container delivery station.

The storage facility may include a delivery section below the first upper vehicle support being void of stacks of storage containers. In this example, the delivery
30 section includes the lower section of the storage space which extends vertically from the first lower vehicle support to a height being at least the height of the container delivery vehicle having, or intended to have, a storage container stored thereon.

The upper vertical position of the lower section of the storage space may be set by
35 one or more horizontal beams, preferably extending from the first separation wall to the opposite boundary of the delivery section (distant from the wall). Most preferably, the storage space contains a plurality of horizontal beams arranged along the entire width of the wall.

The first lower vehicle support may be a lower rail system comprising a first set of lower parallel rails arranged in the lower horizontal plane P_L and extending in a first direction X , and a second set of parallel rails arranged in the lower horizontal plane P_L and extending in a second direction Y which is orthogonal to the first direction X .

5 The first and second sets of parallel rails thus form a grid pattern in the lower horizontal plane P_L comprising a plurality of adjacent grid cells of length L_c and width W_c , each comprising a grid opening defined by a pair of adjacent rails of the first set of lower parallel rails and a pair of adjacent rails of the second set of lower parallel rails. Further, the wheel arrangement of the container delivery vehicle is in
10 this example configured to allow movements in the first direction X and in the second direction Y along the lower rail system.

The upper vehicle support may be an upper rail system comprising a first set of upper parallel rails arranged in the upper horizontal plane P_U and extending in a first direction X , and a second set of parallel rails arranged in the upper horizontal
15 plane P_U and extending in a second direction Y which is orthogonal to the first direction X . The first and second sets of parallel rails form thus a grid pattern in the upper horizontal plane P_U comprising a plurality of adjacent grid cells of length L_c and width W_c , each comprising a grid opening defined by a pair of adjacent rails of the first set of lower parallel rails and a pair of adjacent rails of the second set of
20 upper parallel rails. The wheel arrangement of the container handling vehicle is in this example configured to allow movements in the first direction X and in the second direction Y along the upper rail system.

The upper vehicle support and the lower vehicle support may have an identical, or near identical, configuration.

25 The first separation wall may further comprise a first upper opening sized and positioned to allow the container handling vehicle to pass through and a first upper closable gate configured to open and close the first upper opening.

The storage facility may further comprise a second upper vehicle support such as a rail system extending in the upper horizontal plane (P_U) and arranged relative to the
30 first upper vehicle support such that the container handling vehicle may move between the storage space and the transit space through the first upper opening, preferably without any need of external intervention. As described above for the first and second lower vehicle supports and for the second and third lower vehicle support, the arrangement of the first and second upper vehicle supports may be
35 implemented by aligning the vehicle support relative to each other or adding a link which bridges the two vehicle supports, or a combination thereof. The two vehicle supports may also constitute one integrated support.

The first upper opening may have a size corresponding to at least the width of two side-by-side positioned container handling vehicles, for example the width of three.

The second separation wall may comprise a second upper opening sized and positioned to allow the container handling vehicle to pass through from the transit space to the handling space and from the handling space to the transit space and a second upper closable gate configured to open and close the second upper opening.

5 The opening and closing may preferably be controlled remotely. Further, the closing of the first and second upper opening by the first and second upper closable gate, respectively, is preferably arranged such that fluid-tight closures are achieved, for example air-tight/gas-tight.

10 If a gas regulating device is present, the gas regulating device may advantageously comprise a gas container which includes means to convert a gas or gas mixture having an initial flammable gas concentration C_{oi} to a converted gas / gas mixture having a final flammable gas concentration C_{of} being less than the initial flammable gas concentration C_{oi} and at least one gas inlet allowing fluid communication between the gas container and the storage space.

15 The gas regulating device is preferably installed outside the storage space and configured to at least partly replace an initial gas within the storage space with the converted gas by guiding the converted gas from the gas container into the storage space via the at least one gas inlet.

20 The initial gas, i.e. prior to conversion, may be air at atmospheric pressure (1 atm.) containing circa 78 % nitrogen and 21 % oxygen. (Herein, the percentage of a gas in a mixture of gases is expressed as percent by volume.) The flammable gas concentration (C_{oi} , C_{of}) is in this example the concentration of oxygen gas (O_2). For example, the result of the conversion by the gas regulating device may be to reduce the oxygen concentration from the initial 21 % to a concentration equal or less than
25 16 %.

The conversion may be performed by means well known in the art. See for example, the article "WagnerImpulse" in the magazine "The Wagner Group Customer magazine" (3/2018), for reduction of oxygen concentration in air within an air container. The article is hereby incorporated by reference.

30 The storage facility may further comprise one or more flammable gas sensors, such as one or more O_2 gas sensors, installed within the transit space for measurement of the concentration of flammable gas. The measurements may be performed continuously or at a specific time interval, or on request by an operator, or a combination thereof. Such flammable gas sensors may also be installed within the
35 storage space and/or the handling space.

In this exemplary configuration the gas regulating device is configured to at least partly replace an initial gas / gas mixture within the storage space with the

converted gas / gas mixture by guiding the converted gas / gas mixture from the gas container into the storage space via the at least one gas inlet.

5 In a second aspect, the invention concerns a method for reducing a risk of fire within or at a storage and retrieval system arranged inside a storage space of a storage facility in accordance with any of the features described above.

10 The method comprises the steps of converting a gas or gas mixture within the gas container having an initial flammable gas concentration CO_i , such as 21 % O_2 , to a converted gas / gas mixture having final flammable gas concentration CO_f being less than the initial flammable gas concentration CO_i , such as less than 16 % O_2 , and at least partly replacing an initial gas / gas mixture within the storage space with the converted gas / gas mixture by guiding the converted gas / gas mixture from the gas container into the storage space via the at least one gas inlet.

15 The method may further comprise the step of picking up at least one storage container of the plurality of storage containers stored within the storage grid using the lifting device, lowering the at least one storage container vertically down to the container delivery vehicle within the delivery section, opening the first lower closable gate, moving the container delivery vehicle from the lower section of the storage space into the lower section of the transit space through the first lower opening and closing the first lower closable gate.

20 The first lower closable gate may be opened by a motor such as a remotely operated motor or opened by horizontal pressure from the container delivery vehicle intended to pass through, or a combination thereof.

Further, the first lower closable gate may be closed by use of the motor, or by letting the gate fall down due to gravitational force, or a combination thereof.

25 The first lower closable gate may comprise a door-like structure, i.e. a broadly planar structure having a size corresponding to the first upper opening. Alternatively, the first lower closable gate may comprise a plurality of strips suspended from the upper frame of the first lower opening, the strips hanging down and aligned edge-by-edge to close the first lower opening, and thereby allowing the container delivery vehicle to pass through by strip separation during exertion of pressure, followed by realignment of the strips edge-by-edge after a complete passage, to re-close the first lower opening.

30

35 If the storage facility further comprises a handling space for handling storage containers transported from or to the storage and retrieval system within the storage space and a second separation wall separating the handling space and the transit space, wherein the second separation wall comprises a second lower opening sized and positioned to allow the container delivery vehicle to pass through and a second

lower closable gate configured to open and close the second lower opening, the method may further comprise the steps of opening the second lower closable gate, moving the container delivery vehicle from the lower section of the transit space into the handling space through the second lower opening and closing the second lower closable gate. The second lower closable gate may be opened and closed in the same way as the first lower closable gate.

The method may further comprise the step of regulating a time interval Δt between the closing of the first lower closable gate and the opening of the second lower closable gate to ensure that the final flammable gas concentration C_{of} within the storage space is kept below a predetermined maximum level $C_{O,MAX}$, for example 16 % O₂ gas. The regulation of the time interval may be controlled by a remote-control system, preferably the same control system operating the container handling vehicles.

The method may further comprise the step of measuring the final flammable gas concentration (C_{of}) within the transit space continuously or at specific time intervals or on a request by an operator a combination thereof. The measurement may be performed by use of a gas sensor as mentioned above. Moreover, the measurement and setup may also be arranged within the storage space and/or the handling space.

The method may further comprise the step of continuously regulating the gas within the storage space to further reduce the final flammable gas concentration (C_{of}) or to maintain the final flammable gas concentration (C_{of}) constant or near constant. The regulation of the gas may also be performed at intervals and/or on request by an operator. An example of the latter may be when the O₂ concentration rises above a certain predetermined level.

In a third aspect, the invention concerns a method for extinguishing a fire within or at a storage and retrieval system arranged inside a storage space of a storage facility in accordance with any of the features described above.

The method comprises the steps of injecting a fire extinguishing substance into the storage space when a fire is detected / observed. The fire extinguishing substance may for example be a fire extinguishing fluid such as water or CO₂.

As for the second aspect, the method may further comprise the step of picking up at least one storage container of the plurality of storage containers stored within the storage grid using the lifting device, lowering the at least one storage container vertically down to the container delivery vehicle within the delivery section, opening the first lower closable gate, moving the container delivery vehicle from the lower section of the storage space into the lower section of the transit space through the first lower opening and closing the first lower closable gate, for

example by use of a dedicated motor and/or simply letting the gate close due to the influence of gravity.

5 In a fourth aspect, the invention concerns a method for cooling a storage space of a storage facility in accordance with any of the features described above to a desired temperature below the ambient temperature.

The method comprises the steps of cooling the storage space to a predetermined temperature, for example down to a temperature at below 10°C. The storage space may be cooled by a cooling means, which may for example comprise refrigeration circuits and/or condensing units.

10 As for the second and third aspects, the method may further comprise the step of picking up at least one storage container of the plurality of storage containers stored within the storage grid using the lifting device, lowering the at least one storage container vertically down to the container delivery vehicle within the delivery section, opening the first lower closable gate, moving the container delivery vehicle
15 from the lower section of the storage space into the lower section of the transit space through the first lower opening and closing the first lower closable gate, for example by use of a dedicated motor and/or simply letting the gate close due to the influence of gravity.

Brief description of the drawings

20 The following drawings are appended to facilitate the understanding of the invention. The drawings show prior art and embodiments of the invention, which will now be described by way of example only, where:

Fig. 1 is a perspective view of a prior art automated storage and retrieval system comprising an upper transport rail system onto which a plurality of remotely
25 operated container handling vehicles is operating and a storage grid for storing stacks of containers.

Fig. 2 is a top view of a double rail grid cell of the storage grid shown in Fig. 1.

Fig. 3 is a perspective view of a prior art container handling vehicle having a cantilever for containing storage containers underneath.

30 Fig. 4 is a side view of a storage facility according to a first embodiment of the invention.

Fig. 5 is a perspective view of part of the storage grid as in Fig. 1 and a lower delivery rail system onto which a plurality of remotely operated container handling vehicles is operating.

35 Fig. 6 is a perspective view of a container delivery vehicle operable on the lower delivery rail system shown in Fig. 5.

Fig. 7 is a side view of a storage facility according to a second embodiment of the invention.

Fig. 8 is a side view of a storage facility according to a third embodiment of the invention.

5 Detailed description of the invention

In the following, embodiments of the invention will be discussed in more detail with reference to the appended drawings. It should be understood, however, that the drawings are not intended to limit the invention to the subject-matter depicted in the drawings. Furthermore, even if some of the features are described in relation to the system only, it is apparent that they are valid for the related methods as well, and vice versa.

With reference to Fig. 1 the storage grid 104 of the automated storage and retrieval system 1 forming part of a framework structure 100 contains in total 1144 grid cells, where the width and length of the storage grid 104 corresponds to the width and length of 143 grid columns. The top layer of the framework structure 100, above the storage grid 104, is an upper transport rail system 108 onto which a plurality of container handling vehicles 200 are operated.

The framework structure 100 of the inventive automated storage and retrieval system 1 (hereinafter abbreviated the storage system 1) is constructed in accordance with the prior art framework structure 100 described above, i.e. a plurality of upright members 102 and one or more horizontal members 103 which are supported by the upright members 102.

The upper transport rail system 108 comprises parallel rails 110, 111 oriented in the X direction and the Y direction, respectively, and arranged across the top of storage columns 105 containing stacks 107 of storage containers 106 (hereinafter abbreviated containers 106). The horizontal area of a single grid cell 122, i.e. along the X and Y directions, may be defined by the distance between adjacent rails 110 and 111, respectively. In Fig. 1, such a grid cell 122 is marked on the upper transport rail system 108 by thick lines.

As illustrated in Fig. 2, each grid cell 122 may be described with a grid cell width W_c and a grid cell length L_c , thereby creating a grid opening 115 of width W_o and length L_o . Each grid location is associated with a grid cell 122.

The upper transport rail system 108 allows container handling vehicles 200 adapted for movements on rails to move horizontally between different grid locations in an accurate and stable manner.

In Fig. 1 the storage grid 104 comprising the storage columns 105 is shown with a height of eight cells. It is understood, however, that the storage grid 104 can in principle be of any size. In particular, it is understood that the storage grid 104 can be considerably wider and/or longer than disclosed in Fig. 1. For example, the storage grid 104 may have a horizontal extension of more than 700x700 grid cells 122. Also, the grid 104 can be considerably deeper than disclosed in Fig. 1. For example, the storage grid 104 may be more than ten grid cells 122 deep.

The container handling vehicles 200 may be of any type known in the art, e.g. any one of the automated container handling vehicles disclosed in WO2014/090684A1, in NO317366 or in WO2015/193278A1.

Fig. 1 shows container handling vehicles 200 of the type disclosed in WO2015/193278A1 while Fig. 3 shows a container handling vehicle 200 of the type disclosed in NO317366, i.e. a container handling vehicle 200 comprising a vehicle body 202, a set of wheels 201 attached to the vehicle body 202 and a cantilever having a lifting device 203 underneath. The lifting device 203 is configured to lift and lower containers 106 from and into storage columns 105, respectively.

Fig. 4 shows a side view of a storage facility according to a first embodiment of the invention. Positive X-, Y- and Z-directions are directed into the drawing, from left to right of the drawing and from top to bottom of the drawing, respectively.

The storage facility is divided into three fluid-tight sections 2-4 by external vertical walls arranged on both sides of the storage system 1 in the X and Y direction and a horizontal base 14 and ceiling 15 in the Z direction, thus setting the external boundaries of the storage facility, and two internal spaced apart vertical separation walls, hereinafter called a first separation wall 6 and a second separation wall 8, both arranged at one side of the storage system 1 in the Y direction (to the right in Fig. 4). Note that fluid-tight sections mean herein fluid-tight during the time periods when the gates at the boundaries of the sections are in closed positions. Further, fluid-tight means no or insignificant leakage of gaseous substances such as gas and/or vapor.

The three sections are defined as:

- a storage space 2 situated to the left of the first separation wall 6 into which an automated storage and retrieval system 1 (having a first upper transport rail system 108) of the type shown in Fig. 1 is arranged,
- a transit space 3 situated between the first separation wall 6 and the second separation wall 8 containing a second upper transport rail system 108' attached, or integrated with, the first upper transport rail system 108 within the storage space 2 and
- a handling space 4 situated to the right of the second separation wall 8 operating in air at 1 atmosphere, containing a third upper transport rail

system 108'' attached, or integrated with, the second upper transport rail system 108'.

The first, second and third upper transport rail systems 108, 108', 108'' are all arranged at upper level P_U .

- 5 The first and separation walls 6, 8, and thus the transit space 3 and the handling space 4, may additionally or alternatively be arranged to the left of the storage system 1.

10 As seen in Fig. 4, the handling space 4 contains a container delivery station 150 arranged at or near the base 14 of the storage facility and a container guiding column 9 extending between the third upper transport rail system 108'' and the delivery station 150. The container guiding column 9 is configured to guide containers 106 having been inserted into the column 9 by a container handling vehicle 200 to or from the delivery station 150.

15 The container guiding column 9 is in the example shown in Fig. 4 further equipped with a lower platform 9a onto which the container(s) 106 is/are placed prior to being moved into the delivery station 150 during transport out of the storage system 1 or placed prior to being lifted up by a container handling vehicle 200 to the third upper transport rail system 108'' during transport into the storage system 1.

20 The movement of the container 106 between the lower platform 9a and the delivery station 150 may be carried out by a human operator 51 or a robotic operator or a conveyor belt or a combination thereof.

Further, the lifting or lowering of the container(s) 106 through the container guiding column 9 may be performed by a dedicated lift instead of, or in addition to, using the lifting device 203 within the container handling vehicle 200.

25 In addition to, or as an alternative to, the container guiding column 9 transporting the containers 106 vertically to the delivery station 150, the transport from the third upper transport rail system 108'' to the delivery station 150 may be performed by one or more downward tilted conveyor belts (not shown).

30 The attachment or integration of the first upper transport rail system 108 with the second upper transport rail system 108', as well as the attachment or integration of the second transport rail system 108' with the third upper transport rail system 108'', is made such that a container handling vehicle 200 is allowed to move freely between the different rail systems 108, 108', 108''.

35 The first and second separation walls 6, 8 both comprise at least one upper opening 6a, 8a located immediately above the two linkage points of the upper transport rail systems 108, 108', 108'', i.e. between the first and second upper transport rail

systems 108, 108' and between the second and third upper transport rail systems 108', 108'', and has a size that allows at least one container handling vehicle 200 to pass through, for example a height above groove(s) of the rails that is 10 % higher than the total height of the container handling vehicle 200 (including any top situated devices such as antennae) and a width corresponding to the distance in the X direction across one grid cell 122 or two grid cells 122 or three grid cells 122. The groove is herein defined as the confined track of the rail into which the wheel of the vehicle 200 is guided.

Each upper opening 6a, 8a is equipped with a upper closable gate 6b, 8b that may be opened when a container handling vehicle 200 is moving through the upper openings 6a, 8a between the different rail systems 108, 108', 108'' and closed when the container handling vehicle 200 is completely through the respective upper opening 6a, 8a.

The opening and closing of the upper gates 6b, 8b is preferably controlled by a remote-control system 109 also controlling the movement of the container handling vehicles 200 and any charging stations (not shown) present on the storage system 1. In this exemplary embodiment, the upper gates 6b, 8b include a motorized system (not shown) configured to allow necessary movements of the upper gates 6b, 8b, for example a motor driving a swivel causing a pivotable movement of the upper gates 6b, 8b or a motor driving a linear actuator causing a linear, vertical movement of the upper gates 6b, 8b. A winch system configured to lift/ lower the upper gates 6b, 8b or pivot the upper gates 6b, 8b is also foreseeable.

It is however feasible that the opening and closing are performed without use of any motor systems. For example, at least one of the upper gates 6b, 8b may be hinged to the respective separation wall 6, 8 at the upper edge of the upper opening 6a, 8a such that the upper gate 6a,8a pivots into the space 2, 3, 4 where the container handling vehicle 200 is moving by a pushing force exerted by the vehicle 200. The closing of the upper gate 6b, 8b is thus achieved by the gravitational force, possibly aided by adding weights on the upper gates 6b, 8b and/or installing a mechanical and/or magnetic closing mechanism between the upper gates 6b, 8b and the boundaries of the separation wall 6, 8 setting the upper opening 6a, 8a.

In order to at least reduce the risk of fire within the storage space 2 where the storage system 1 is located, the storage facility is equipped with a gas regulating device 10 comprising a gas container 10a located outside the storage space 2, a gas inlet 10c going into the storage space 2 and a gas tube 10b in fluid communication between the gas container 10a and the gas inlet 10c. With this arrangement, gas is allowed to flow between the gas container 10a and the storage space 2.

The gas container 10a comprises means for reducing (or increasing) a gas element in a gas mixture such as O₂ gas in air. Such means are known in the art and will thus

not be explained further herein. See for example the article “WagnerImpulse” in the magazine “The Wagner Group Customer magazine” (3/2018).

- 5 In dry air, the concentration of the flammable gas oxygen is about 21 %. If the oxygen concentration is lowered to 16 % or below, the risk of fire is significantly reduced. In air, a fire may occur for example due to sparks from the movements of the container handling vehicles 200 and/or sparks from the charging stations (not shown) for charging the batteries within the vehicles 200 and/or combustion of contents within containers 106 and/or accidental heating such as may be caused by sunlight hitting flammable material within the storage system 1.
- 10 The fluid-tight separation between the storage space 2 and the handling space 4 ensures that the container handling vehicles 200 may store and fetch containers 106 located within an oxygen reduced atmosphere that has a reduced or insignificant risk of fire but which represents a health risk for humans, and to receive and deliver containers 106 to a workspace in which humans may safely work.
- 15 Moreover, by arranging a fluid-tight transit space 3 between the storage space 2 and the handling space 4, the amount of fluid leakage from the storage space 2 during transit of container handling vehicles 200 between the storage space 2 and the handling space 4 may be minimized. In effect, the separation walls 6, 8 and intervening transit space 3 act as an airlock (a chamber with two air-tight doors in series (upper opening 6a, 8a, sealed by upper gates opening 6b, 8b) which
- 20 preferably do not open simultaneously).
- For example, air initially containing about 21 % oxygen gas within both the storage space 2 and the transit space 3 may be replaced (using the gas regulating device 10) by an air-like gas mixture having a reduced oxygen gas concentration such as 16 %
- 25 or less. The oxygen concentration in the air within the handling space 4 is however not replaced and is kept at the usual atmospheric level.
- During operation, the oxygen concentration in the transit space 3 will increase due to repeated opening of the second upper closable gate 8b, thereby causing an exchange of gas between the handling space 4 and transit space 3. However, since
- 30 the first upper closable gate 6b will be closed when the second upper closable gate 8b is opened, little or insignificant air present in the handling space 4 will be exchanged with the gas mixture present in the storage space 2. Hence, an undesired increase in oxygen concentration during operation will be less rapid in the storage space 2 than in the transit space 3.
- 35 It is advantageous to monitor the oxygen concentration in the storage facility, in particular within the storage space 2. In the exemplary embodiment shown in Fig. 4 the storage facility is equipped with oxygen gas sensor 12 in the storage space 2, oxygen sensor 11 in the transit space 3 and oxygen sensor 13 in the handling space

4. All of these oxygen gas sensors 11-13 are shown in Fig. 4 mounted to the ceiling 15 of the storage facility. However, the oxygen gas sensors may be mounted anywhere within their respective spaces 2-4.

5 The purpose of the oxygen gas sensor 12 in the storage space 2 is primarily to ensure that the oxygen concentration remains below a predetermined maximum concentration, for example 16 % oxygen concentration, while the purpose of the oxygen gas sensor 13 in the handling space 4 is primarily to ensure that the oxygen concentration remains at a level considered safe for humans. Finally, the purpose of the oxygen gas sensor 11 in the transit space 3 is primarily to monitor the degree of
10 any leakage between the storage space 2 and the transit space 3, as well as any leakage between the handling space 4 and the transit space 3.

The measurements by gas sensors 11-13 may be made continuously, at time intervals, by request from an operator or a combination thereof.

But the inventive storage facility is not limited to reduce the risk of fire.

15 Another example of a range of use for a storage facility allowing control of gas concentration is storage of fresh food. Prior Art tests have shown that that fruits such as apples may be best long-term stored in an atmosphere comprising 1 % O₂ and 1-2.5 % CO₂. The O₂ gas may be replaced with N₂ gas.

20 As mentioned above, the storage facility may alternatively, or in addition, comprise a fire extinguishing device and/or a cooling facility.

A storage facility having both a cooling facility for cooling the storage space to temperatures below 10°C and a gas regulating device 10, 10a-c, may create near ideal condition for storage of fresh food.

25 This fresh food configuration of the storage facility may be supplemented by a fire extinguishing device to decrease fire hazards.

A different storage system 1 is shown in part in Fig. 5 where the upright members 102 constitute part of a framework structure 100 onto which an upper transport rail system 108 with a plurality of container handling vehicles 200 are operating.

30 Below the upper transport rail system 108, near the base 14, another framework structure comprising vertical columns and a lower delivery rail system 308 is shown which at least partly extends below some of the storage columns 105 of the storage grid 104. As for the higher framework structure 100, a plurality of vehicles 300 may operate on the lower delivery rail system 308. Similarly to or the same as the upper transport rail system 108, the lower delivery rail system 308 comprises a first set of
35 parallel rails 310 directed in a first direction *X* and a second set of parallel rails 311

directed in a second direction Y perpendicular to the first direction X , thereby forming a grid pattern in a lower horizontal plane P_L (arranged closer to the base 14 compared to the upper horizontal plane P_U) comprising a plurality of rectangular and uniform grid locations or grid cells 322 (indicated in Fig. 5 by thicker lines).
 5 Each grid cell 322 of this lower delivery rail system 308 comprises a grid opening 315 being delimited by a pair of neighboring rails 310a, 310b of the first set of rails 310 and a pair of neighboring rails 311a, 311b of the second set of rails 311. The volume in the vertical direction Z between the delivery rail system 308 and the storage columns 105 directly above the delivery rail system 308 and in the
 10 horizontal plane P_L within the storage space 2, is hereinafter called a lower storage space 2'. Further, the section of the storage grid 104 between the lower storage space 2' and the upper transport rail system 108 is hereinafter called a delivery section 121 (see Fig. 7).

The part of the lower delivery rail system 308 that extends below the storage
 15 columns 105 is aligned such that its grid cells 322 in the horizontal plane P_L coincide with the grid cells 122 of the upper transport rail system 108 in the horizontal plane P_U .

Hence, with this particular alignment of the two rail systems 108, 308, a container 106 being lowered down into a storage column 105 within the delivery section 121
 20 (i.e. located above the lower storage space 2') by a container handling vehicle 200 may be placed within or on a storage container support 302 of a delivery vehicle 300 having moved into position directly below the storage column 105 in question.

Fig. 6 shows an example of such a container delivery vehicle 300 comprising a wheel assembly 301 similar to the wheel assembly 201 described for the prior art
 25 container handling vehicle 200 and a storage container support 302 for receiving and supporting a container 106 delivered by a container handling vehicle 200. The storage container support 302 may be a tray (as shown in Fig. 6), a plate, or any other shapes that is able to support the container during horizontal movements along the lower rail system 308.

30 After having received a container 106, the container delivery vehicle 300 may drive in X and Y directions along the lower horizontal plane P_L to another location of the lower delivery rail system 308.

Fig. 7 shows a storage facility according to a second embodiment of the invention.

35 As for the first embodiment, the storage facility comprises a storage space 2, a transit space 3 and a handling space 4, wherein at least a part of the storage system

1 as described above is installed on a base 14 via a base support 16 exemplified in Fig. 7 by a plurality of upstanding support rods.

A plurality of container handling vehicles 200 are operable on an upper transport rail system 108 extending in an upper horizontal plane P_U .

5 However, unlike the storage facility of the first embodiment, the container handling vehicles 200 may only operate within the storage space 2. Instead, when an instruction from the remote control system 109 instructs the storage system 1 to retrieve a particular container 106 from the storage grid 104, a container handling
10 vehicle 200 (after having lifted the container 106 from the respective stack 107 as described above) transports the container 106 to a storage column 105 above the delivery section 121, and subsequently lowers the container 106 down to a waiting container delivery vehicle 300.

After having received the container 106 into or on the storage container support 302, the container delivery vehicle 300 moves (by use of the wheel arrangement
15 301) through a first lower opening 6b of the first separation wall 6 and onto a second lower delivery rail system 308' in a lower transit space 3' of the transit space 3.

In a similar or identical way as described for the first and second transport rail systems 108, 108' of the first embodiment, the second lower delivery rail system
20 308' is configured relative to the first lower delivery rail system 308 such that the container delivery vehicle 300 may move freely between the two lower delivery rail systems 308, 308'.

In further similarity to the upper transport rail systems 108, 108' of the first embodiment, a first lower closable gate 6d is mounted relative to the first lower
25 opening 6c such that a fluid-tight closure between the storage space 2 and the transit space 3 is achieved when the gate 6d is in a closed position.

In the exemplary configuration of Fig. 7, a vertical termination 123 of the storage grid 104 is shown arranged at the boundary between the delivery section 121 and
30 the lower storage space 2' in which the container handling vehicles 300 are operated. The vertical termination may be one or more horizontal plates, or a plurality of horizontal beams 123, extending across the depth of the storage space 2 in the X direction and at least to the first separation wall 6 along the Y direction.

In Fig. 7, the vertical termination 123 further extends in the Y direction across the transit space 3 to a second separation wall 8. A lower transit space 3' may therefore

be defined as the depth of the transit space 3 or the storage system 1 in the X direction, the distance between the first and second separation walls 6, 8 in the Y direction and the distance between the second delivery rail system 308' and the vertical termination 123 in the Z direction.

5 After the container delivery vehicle 300 has passed through the first lower opening 6c, the first lower closable gate closes the first lower opening 6c while the container delivery vehicle 300 continues to the second separation wall 8, creating a fluid-tight separation between the transit space 3 and the handling space 4 containing a container delivery station 150. Similar to the first separation wall 6, the second
10 separation wall 8 contains a second lower opening 8c situated immediately above the second lower delivery rail system 308' and a second lower closable gate 8d mounted relative to the opening 8c to allow a fluid/gas-tight closure across the second separation wall 8.

As for the first and second lower delivery rail systems 308, 308', the handling space
15 4 contains a third lower delivery rail system 308'' arranged relative to the second lower delivery rail system 308' such that the container delivery vehicle 300 may move freely between the transit space 3 and the handling space 4 through the second lower opening 8c.

The third lower delivery rail system 308'' extends in the Y-direction at least to the
20 to the container delivery station 150, thereby allowing the container delivery vehicle 300 to transport the container 106 from the second lower opening 8c to the container delivery station 150 for further handling by a human and/or robotic operator 151.

As for the first embodiment, it is considered advantageous to install one or more
25 oxygen gas sensors 11-13 at a location within each of the spaces 2-4 to monitor the oxygen concentration, for example in the ceiling 15 of the storage facility. The measurements may be made continuously, at time intervals, by request from an operator or a combination thereof.

Fig. 8 shows a storage facility of a third embodiment of the invention which combines
30 the solution of the first and second embodiments, signifying that both the container handling vehicles 200 and the container handling vehicles 300 may transport containers 106 between the storage space 2 and the handling space 4 for further handling.

In the third embodiment, lower delivery rail systems 308, 308', 308'' and upper transport
35 systems 108, 108', 108'' are set up in each of the spaces within the storage facility separated by the separation walls 6,8. The rail systems 108, 108', 108'', 308, 308', 308'' are interconnected at the lower edge of the respective openings 6a, 8a, 6c, 8c in a similar or equivalent manner as for the first and second embodiments. Further, each opening 6a,

8a, 6c, 8c is equipped with a closable gate 6b, 8b, 6d, 8d installed in a similar or equivalent manner as for the first and second embodiments.

5 In Fig. 8, the vertical termination 123 further extends in the Y direction into the handling space 4 to, or near to, a container delivery station 150. A lower handling space 4' can thus be defined as the depth of the handling space 4 in the X direction, the distance between the second separation wall 8 and the container delivery station 150 in the Y direction and the distance between the third delivery rail system 308'' and the vertical termination 123 in the Z direction. In this particular configuration, the vertical termination 123 includes the lower platform 9a situated within the
10 container guiding column 9 adjacent to the container delivery station 150.

In the preceding description, various aspects of the storage facility according to the invention have been described with reference to the illustrative embodiment. For purposes of explanation, specific numbers, systems and configurations were set forth in order to provide a thorough understanding of the system and its workings.
15 However, this description is not intended to be construed in a limiting sense. Various modifications and variations of the illustrative embodiment, as well as other embodiments of the system, which are apparent to persons skilled in the art to which the disclosed subject matter pertains, are deemed to lie within the scope of the present invention.

List of reference numerals / letters:

1	Automated storage and retrieval system
2	Storage space
2'	Lower storage space
3	Transit space
3'	Lower transit space
4	Handling space
4'	Lower handling space
6	First separation wall
6a	First upper opening
6b	First upper closable gate
6c	First lower opening
6d	First lower closable gate
7	Horizontal beam separating transit space and delivery space
8	Second separation wall
8a	Second upper opening
8b	Second upper closable gate
8c	Second lower opening
8d	Second lower closable gate
9	Container guiding column
9a	Lower platform
10	Gas regulating device
10a	Gas container
10b	Gas tube
10c	Gas inlet
11	Flammable gas sensor / oxygen gas sensor (in transit space)
12	Flammable gas sensor / oxygen gas sensor (in storage space)
13	Flammable gas sensor / oxygen gas sensor (in handling space)
14	Base of storage facility
15	Ceiling of storage facility
16	Base support
100	Framework structure
102	Upright members of framework structure
103	Horizontal members of framework structure
104	Storage grid / three-dimensional grid
105	Storage column
106	Storage container
107	Stack
108	First upper vehicle support / first upper transport rail system
108'	Second upper vehicle support / second upper transport rail system
108''	Third upper vehicle support / third upper transport rail system

109	Control system
110	First set of upper parallel rails in first direction (X)
110a	First rail of upper neighboring rails 110
110b	Second rail of upper neighboring rails 110
111	Second set of upper parallel rails in second direction (Y)
111a	First rail of upper neighboring rails 111
111b	Second rail of upper neighboring rails 111
115	Grid opening in transport rail system
119	First delivery column
120	Second delivery column
121	Delivery section within storage grid 104
122	Grid cell of transport rail system
123	Vertical termination of the storage grid / horizontal beam / plate
150	Container delivery station
151	Operator
200	Container handling vehicle
201	Wheel arrangement of a container handling vehicle
202	Vehicle body of a container handling vehicle
203	Lifting device of container handling vehicle
300	Container delivery vehicle
301	Wheel arrangement of container handling vehicle
302	Storage container support / tray of a container handling vehicle
308	First lower vehicle support / first lower delivery rail system
308'	Second lower vehicle support / second lower delivery rail system
308''	Third lower vehicle support / third lower delivery rail system
310	First set of lower parallel rails in first direction (X)
310a	First rail of lower neighboring rails 110
310b	Second rail of lower neighboring rails 110
311	Second set of lower parallel rails in second direction (Y)
311a	First rail of lower neighboring rails 111
311b	Second rail of lower neighboring rails 111
315	Grid opening in delivery rail system
322	Grid cell of delivery rail system
<i>X</i>	First direction
<i>Y</i>	Second direction
<i>Z</i>	Third direction
<i>P</i>	Horizontal plane of vehicle support / rail system
<i>P_L</i>	Lower horizontal plane
<i>P_U</i>	Upper horizontal plane
<i>W_c</i>	Width of grid cell 122
<i>L_c</i>	Length of grid cell 122
<i>W_o</i>	Width of grid opening 115

L_o	Length of grid opening 115
C_{O_i}	Initial flammable gas concentration
C_{O_f}	Final flammable gas concentration
$C_{O,MAX}$	Predetermined maximum level of final flammable gas concentration (C_{O_f})

CLAIMS

1. A storage facility comprising:

- a storage space (2) enclosing a storage and retrieval system (1) comprising:
 - a storage grid (104) configured to store a plurality of storage containers (106) in vertical stacks (107);
 - a first upper vehicle support (108) extending in an upper horizontal plane (P_U) above the storage grid (104);
 - a container handling vehicle (200) configured:
 - to transport at least one of the plurality of storage containers (106) by means of a wheel arrangement (201) between at least two locations on the first upper vehicle support (108); and
 - to vertically displace the at least one storage container (106) by means of a lifting device (203),
 - a first lower vehicle support (308) extending in a lower horizontal plane (P_L) below the first upper vehicle support (108); and
 - a container delivery vehicle (300) operating within a lower section (2') of the storage space (2) above the first lower vehicle support (308), the container delivery vehicle (300) being configured to receive the at least one storage container (106) from the container handling vehicle (200) and to transport the at least one storage container (106) between at least two locations on the first lower vehicle support (308) by means of a wheel arrangement (301),
- a transit space (3) comprising:
 - a second lower vehicle support (308') extending in the lower horizontal plane (P_L) and arranged relative to the first lower vehicle support (308) such that the container delivery vehicle (300) may move between the lower section (2') of the storage space (2) and a lower section (3') of the transit space (3), and
- a first separation wall (6) separating the storage space (2) and the transit space (3), wherein the first separation wall (6) comprises:
 - a first lower opening (6c) sized and positioned to allow the container delivery vehicle (300) to pass through between the lower section (2') of the storage space (2) and the lower section (3') of the transit space (3); and
 - a first lower closable gate (6d) configured to open and close the first lower opening (6c).

2. The storage facility according to claim 1, wherein the first lower closable gate (6d) is configured to be remotely opened and closed by use of a remote control system (109).

3. The storage facility according to any one of the preceding claims, wherein the first lower closable gate (6d) is configured to create a fluid-tight seal between the storage space (2) and the transit space (3) when the first lower closable gate (6d) closes the first lower opening (6c).
- 5 4. The storage facility according to any one of the preceding claims, wherein the storage facility further comprises:
- a handling space (4) for handling storage containers (106) transported from or to the storage and retrieval system (1) within the storage space (2); and
 - a second separation wall (8) separating the handling space (4) and the transit space (3), wherein the second separation wall (8) comprises:
 - 10 ○ a second lower opening (8c) sized and positioned to allow the container delivery vehicle (300) to pass through between the lower section (3') of the transit space (3) and a lower section (4') of the handling space (4); and
 - 15 ○ a second lower closable gate (8d) configured to open and close the second lower opening (8c).
5. The storage facility according to claim 4, wherein the second lower closable gate (8d) is configured to be remotely opened and closed by use of a remote control system (109).
- 20 6. The storage facility according to claim 4 or 5, wherein the handling space (4) comprises a third lower vehicle support (308'') extending in the lower horizontal plane (P_L), the third lower vehicle support (308'') being arranged relative to the second lower vehicle support (308') such that the container delivery vehicle (300) may move between the second lower vehicle support (308') and the third lower vehicle support (308'') through the second lower opening (8c) between the lower section (3') of the transit space (3) and the lower section (4') of the handling space (4).
- 25 7. The storage facility according to any one of claims 4 to 6, wherein the handling space (4) comprises a container delivery station (150) configured:
- 30 to receive a storage container (106) transferred by the container delivery vehicle (300) for further handling; or
 - to deliver a storage container (106) to the container delivery vehicle (300) for storing the storage container (106) into the storage and retrieval system (1); or
 - 35 a combination thereof.
8. The storage facility according to claim 7 when dependent from claim 6, wherein the container delivery vehicle (300) is movable along the third lower vehicle support (308'') from the second lower opening (8c) to a location adjacent to the container delivery station (150).

9. The storage facility according to any one of the preceding claims, wherein the storage facility includes a delivery section (121) below the first upper vehicle support (108) being void of stacks (107) of storage containers (106), the delivery section (121) comprising the lower section (2') of the storage space (2) extending vertically from the first lower vehicle support (308) to a height being at least the height of the container delivery vehicle (300) having a storage container (106) stored therein.
10. The storage facility according to any one of the preceding claims, wherein a horizontal beam (123) is arranged at an upper vertical position of the lower section (2') of the storage space (2).
11. The storage facility according to any one of the preceding claims, wherein the first lower vehicle support (308) is a lower rail system comprising a first set of lower parallel rails (310) arranged in the lower horizontal plane (P_L) and extending in a first direction (X), and a second set of parallel rails (311) arranged in the lower horizontal plane (P_L) and extending in a second direction (Y) which is orthogonal to the first direction (X), which first and second sets of parallel rails (310,311) form a grid pattern in the lower horizontal plane (P_L) comprising a plurality of adjacent grid cells (322) of length L_c and width W_c , each comprising a grid opening (315) defined by a pair of adjacent rails of the first set of lower parallel rails (310) and a pair of adjacent rails of the second set of lower parallel rails (311) and wherein the wheel arrangement (301) of the container delivery vehicle (300) is configured to allow movements in the first direction (X) and in the second direction (Y) along the lower rail system (308).
12. The storage facility according to any one of the preceding claims, wherein the upper vehicle support (108) is an upper rail system comprising a first set of upper parallel rails (110) arranged in the upper horizontal plane (P_U) and extending in a first direction (X), and a second set of parallel rails (111) arranged in the upper horizontal plane (P_U) and extending in a second direction (Y) which is orthogonal to the first direction (X), which first and second sets of parallel rails (110,111) form a grid pattern in the upper horizontal plane (P_U) comprising a plurality of adjacent grid cells (122) of length L_c and width W_c , each comprising a grid opening (115) defined by a pair of adjacent rails of the first set of lower parallel rails (310) and a pair of adjacent rails of the second set of upper parallel rails (111) and wherein the wheel arrangement (201) of the container handling vehicle (200) is configured to allow movements in the first direction (X) and in the second direction (Y) along the upper rail system (108).

13. The storage facility according to any one of the preceding claims, wherein the first separation wall (6) further comprises:

- a first upper opening (6a) sized and positioned to allow the container handling vehicle (200) to pass through; and
- 5 - a first upper closable gate (6b) configured to open and close the first upper opening (6a), and

wherein the storage facility further comprises a second upper vehicle support (108') extending in the upper horizontal plane (P_U) and arranged relative to the first upper vehicle support (108) such that the container handling vehicle (200) is movable
10 between the storage space (2) and the transit space (3) through the first upper opening (6a).

14. The storage facility according to claim 13 when dependent at least from claim 6, wherein the second separation wall (8) comprises:

- a second upper opening (8a) sized and positioned to allow the container
15 handling vehicle (200) to pass through from the transit space (3) to the handling space (4) and from the handling space (4) to the transit space (3); and
- a second upper closable gate (8b) configured to open and close the second upper opening (8a).

20 15. The storage facility according to any one of the preceding claims, wherein the storage facility comprises a fire extinguishing device (10,10a-c) configured to inject fire extinguishing substances into the storage space (2) to distinguish a fire there within.

25 16. The storage facility according to any one of the preceding claims, wherein the storage facility comprises a cooling facility configured to lower the temperature within the storage space (2) to a temperature being lower than the temperature outside the storage space (2) before and/or during operation.

17. The storage facility according to claim 16, wherein the cooling facility is arranged at least partly within the storage space (2).

30 18. The storage facility according to any one of the preceding claims, wherein the storage facility further comprises a flammable gas sensor (11) installed within the transit space (3) for measurement of the concentration of flammable gas.

35 19. The storage facility according to any one of the preceding claims, wherein the storage facility comprises a gas regulating device (10,10a-c) arranged in fluid communication with the storage space (2), the gas regulating device (10,10a-c) being configured to regulate a gas composition of a gas within the storage space (2) before and/or during operation.

20. The storage facility according to claim 19, wherein the gas regulating device (10,10a-c) comprises

- a gas container (10a) comprising means to convert a gas having an initial flammable gas concentration (C_{oi}) to a converted gas having a final flammable gas concentration (C_{of}) being less than the initial flammable gas concentration (C_{oi}) and
- at least one gas inlet (10c) allowing fluid communication from the gas container (10a) to the storage space (2),

wherein the gas regulating device (10,10a-c) is configured to at least partly replace an initial gas within the storage space (2) with the converted gas by guiding the converted gas from the gas container (10a) into the storage space (2) via the at least one gas inlet (10c).

21. A method for reducing a risk of fire within or at a storage and retrieval system (1) arranged within a storage space (2) of a storage facility in accordance with claim 20, wherein the method comprises the steps of:

- converting a gas within the gas container (10a) having an initial flammable gas concentration (C_{oi}) to a converted gas having final flammable gas concentration (C_{of}) being less than the initial flammable gas concentration (C_{oi}); and
- at least partly replacing an initial gas within the storage space (2) with the converted gas by guiding the converted gas from the gas container (10a) into the storage space (2) via the at least one gas inlet (10c).

22. The method according to claim 21, wherein the method further comprises the step of:

- picking up at least one storage container (106) of the plurality of storage containers stored within the storage grid (104) using the lifting device (203),
- lowering the at least one storage container (106) vertically down to the container delivery vehicle (300);
- opening the first lower closable gate (6d);
- moving the container delivery vehicle (300) from the lower section (2') of the storage space (2) into the lower section (3') of the transit space (3) through the first lower opening (6c); and
- closing the first lower closable gate (6d).

23. The method according to claim 22, wherein the storage facility further comprises a handling space (4) for handling storage containers (106) transported from or to the storage and retrieval system (1) within the storage space (2) and a second separation wall (8) separating the handling space (4) and the transit space (3), wherein the second separation wall (8) comprises:

- a second lower opening (8c) sized and positioned to allow the container delivery vehicle (300) to pass through; and

- a second lower closable gate (8d) configured to open and close the second lower opening (8c)

and wherein the method further comprises the steps of:

- opening the second lower closable gate (8d);
- 5 - moving the container delivery vehicle (300) from the lower section (3') of the transit space (3) into a handling space (4) through the second lower opening (8c); and
- closing the second lower closable gate (8d).

10 24. The method according to claim 23, wherein the method further comprises the step of:

- regulating a time interval (Δt) between the closing of the first lower closable gate (6d) and the opening of the second lower closable gate (8d) to ensure that the final flammable gas concentration (C_{of}) within the storage space (2) is kept below a predetermined maximum level ($C_{O,MAX}$).

15 25. The method according to any one of claims 21 to 24, wherein the method further comprises the step of:

- measuring the final flammable gas concentration (C_{of}) within the transit space (3).

20 26. The method according to any one of claims 21 to 25, wherein the method further comprises the step of:

- regulating the gas within the storage space (2)
 - o to further reduce the final flammable gas concentration (C_{of}) or
 - o to maintain the final flammable gas concentration (C_{of}) constant or near constant.

1/8

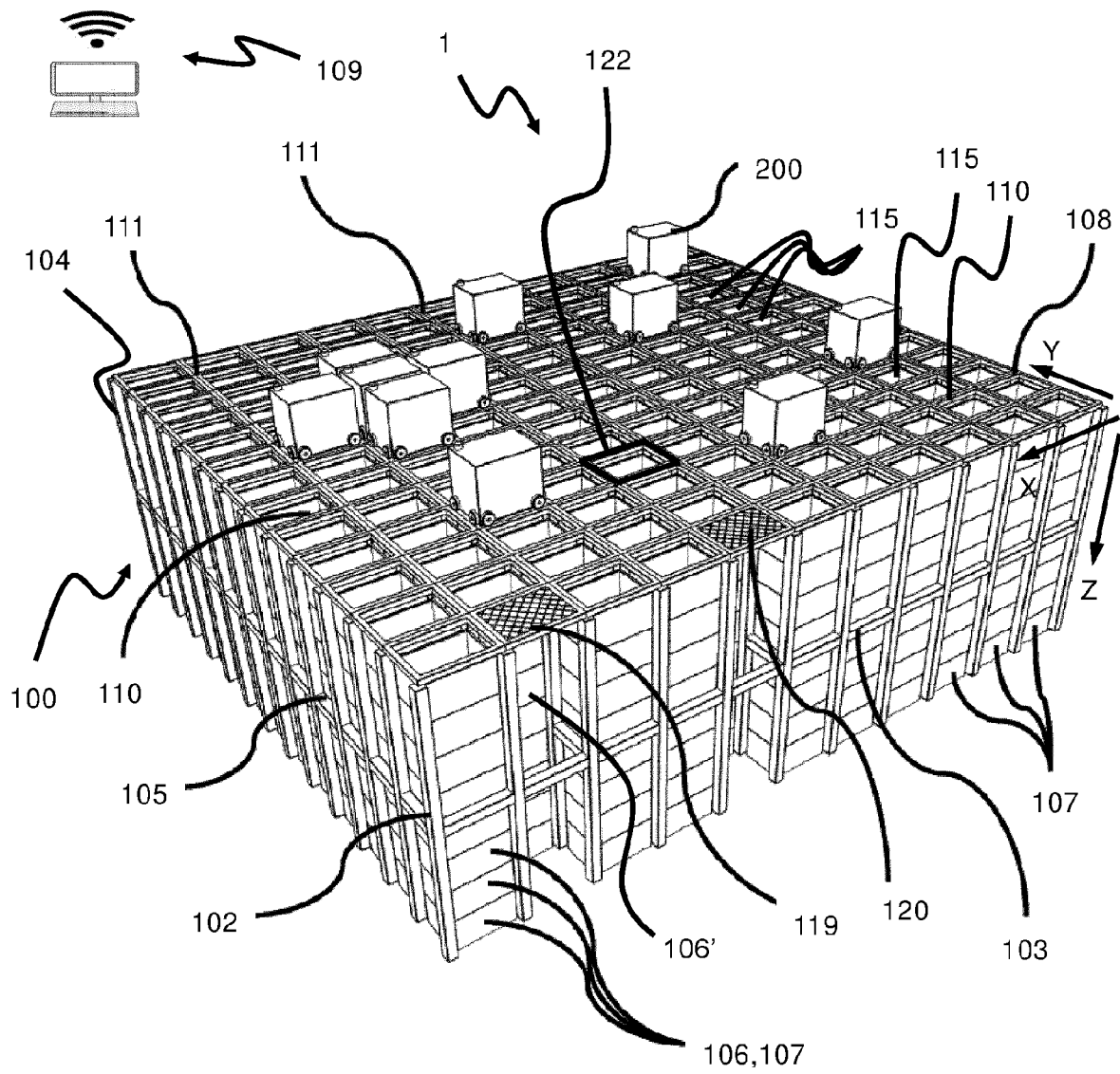


FIG. 1 (PRIOR ART)

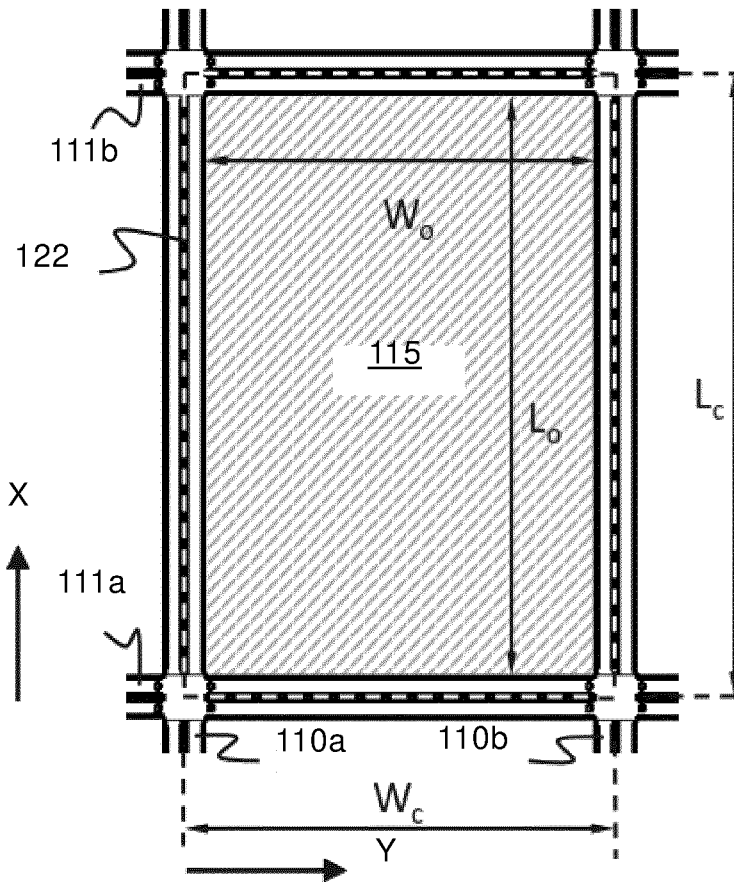


FIG. 2 (PRIOR ART)

3/8

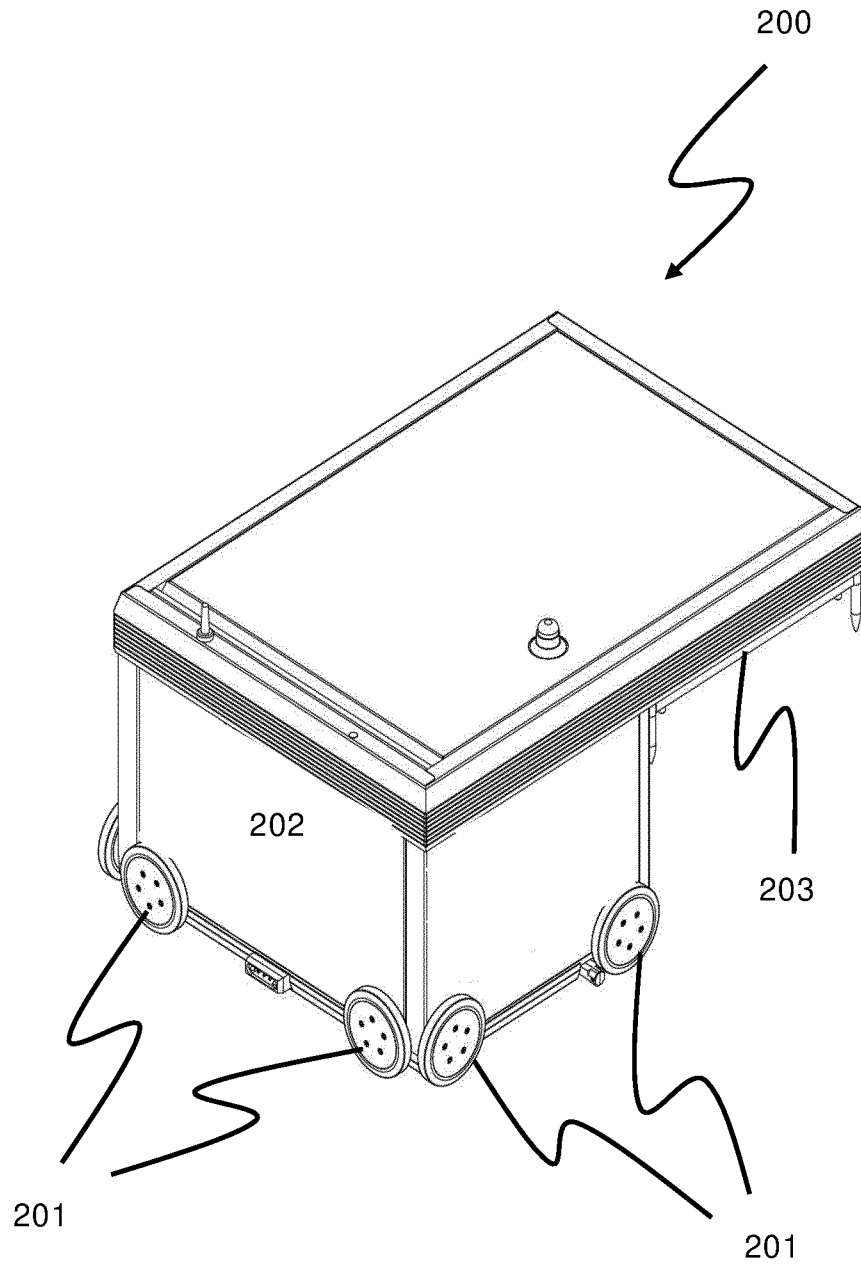


FIG. 3 (PRIOR ART)

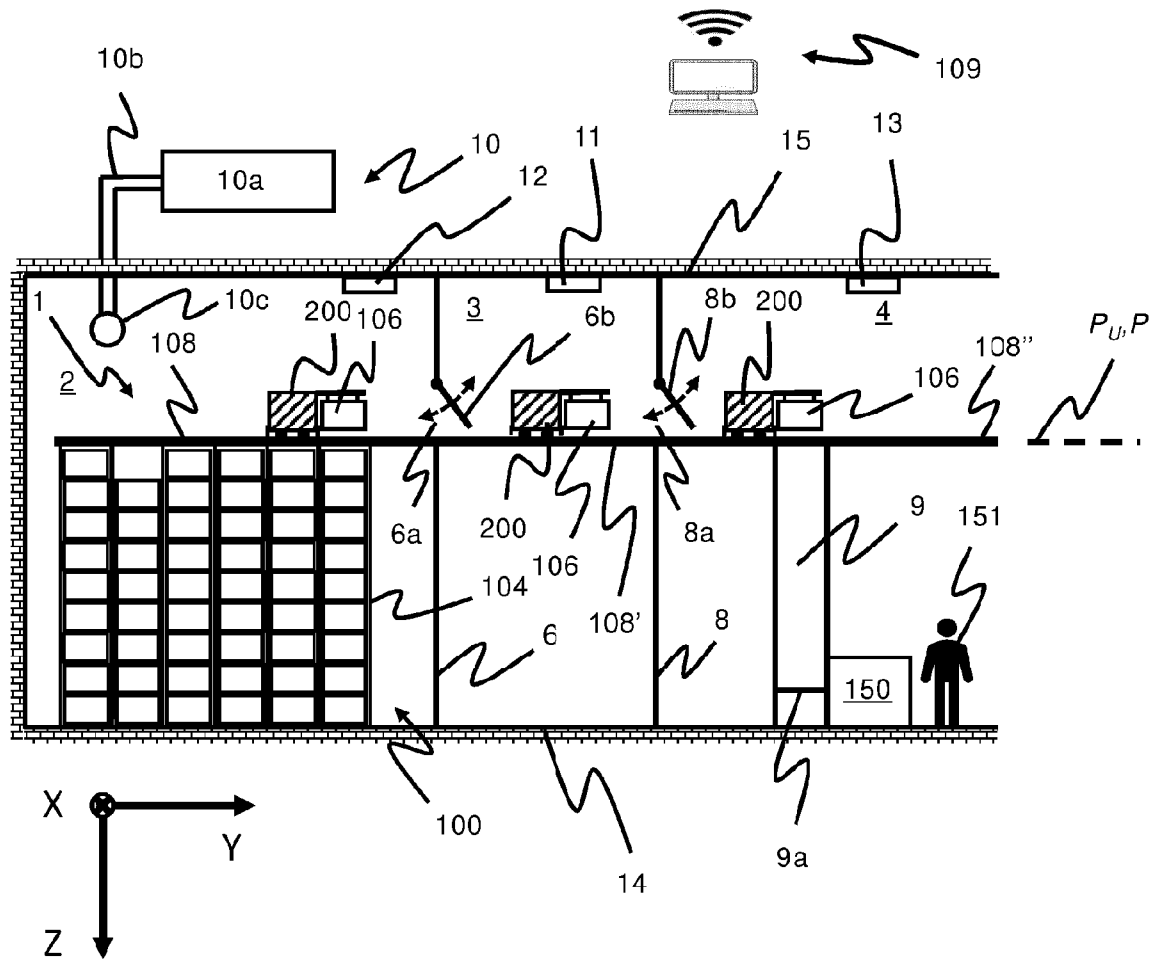


FIG. 4

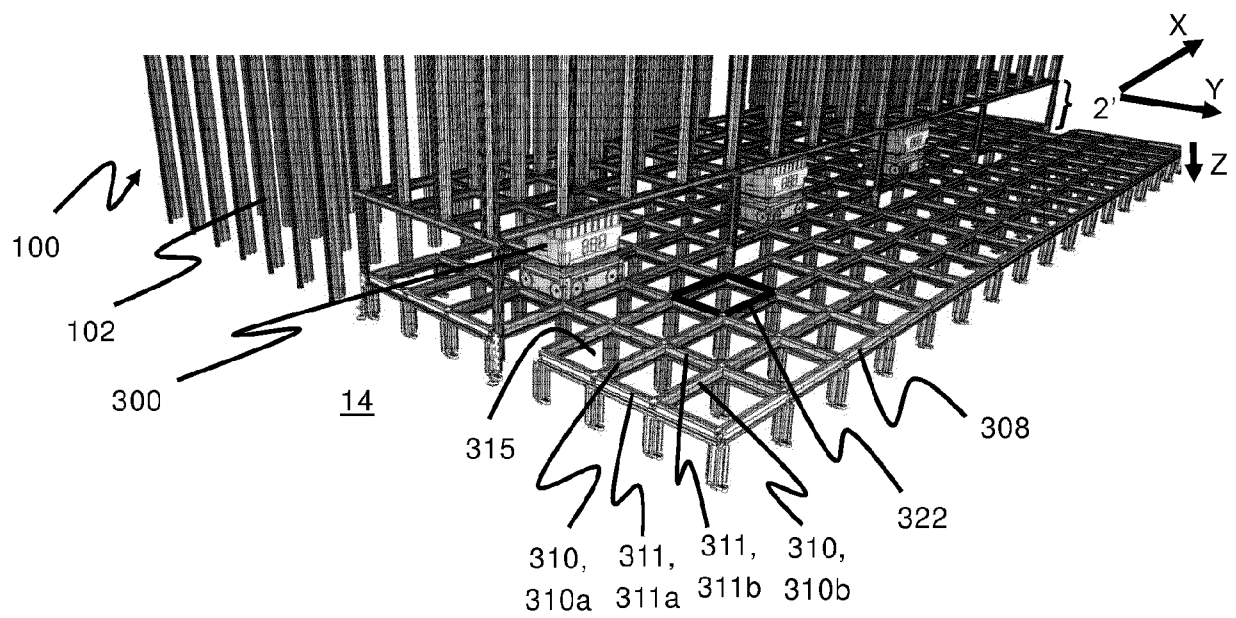


FIG. 5

6/8

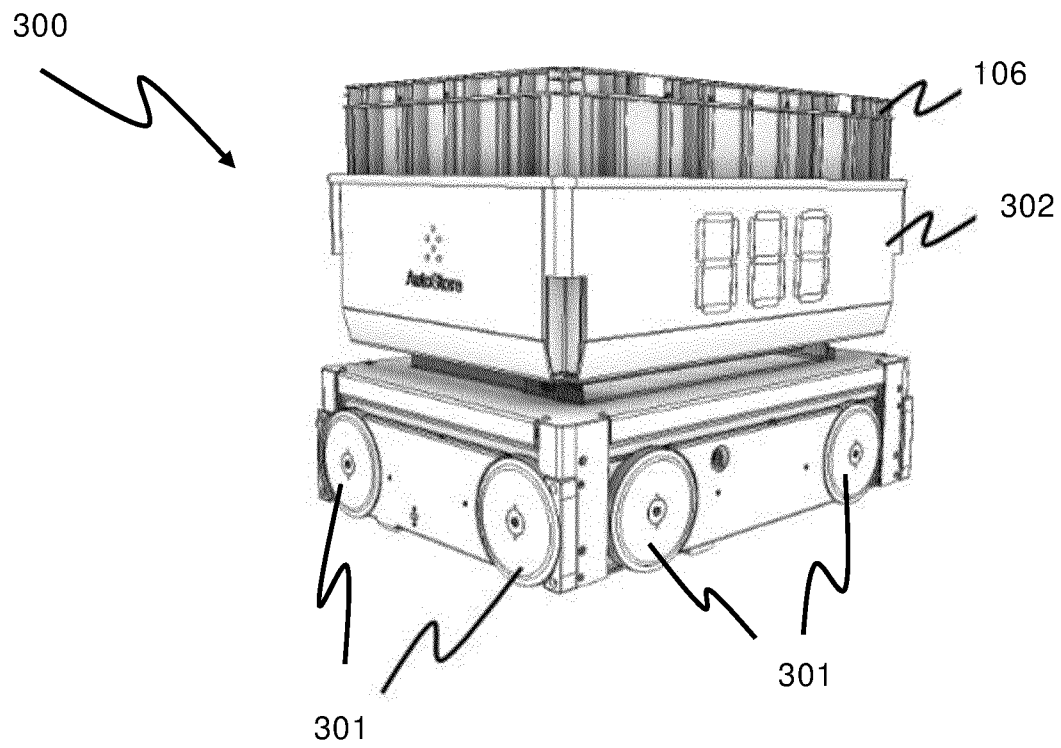


FIG. 6

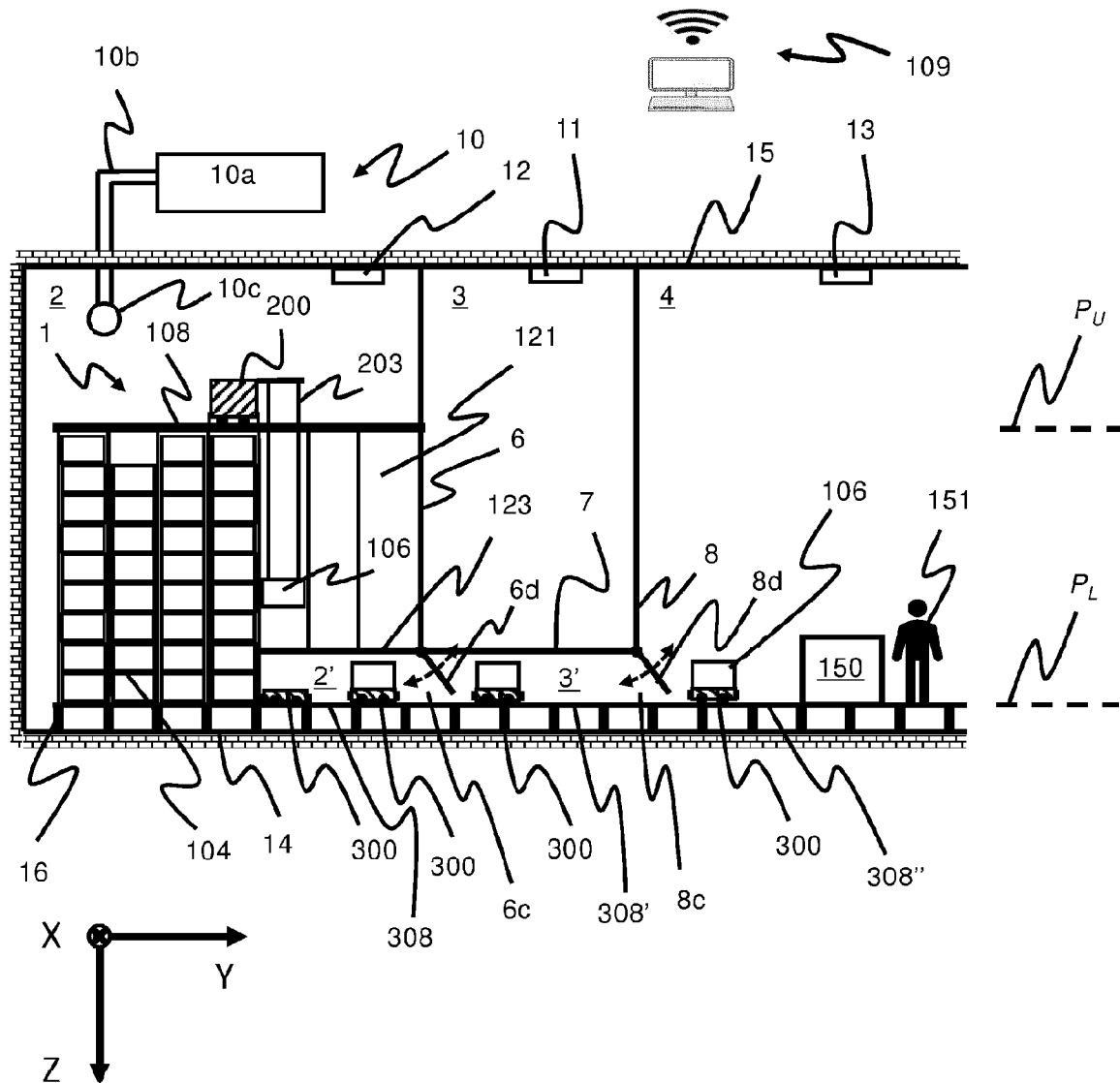


FIG. 7

