

TITLE. Method and system for reducing and preventing emissions from liquid storage tanks.

5 The invention relates to a system for use interiorly in a storage tank, said storage tank being suitable for storing a liquid load, the system comprising: at least one flexible liquid holder for containing the liquid load.

10 Large storage tanks for liquid products, like petroleum and chemical products, usually are of the type "fixed" of "floating" roof tanks.

The "fixed roof" storage tanks have a fixed interior volume. Said storage tanks may be located upon solid base ground like in a storage yard or may be located upon a floating device like a ship, which is arranged for transportation of liquids; or like a tanker; or like a so-called FPSO (Floating Production, Storage and Offloading) provided with storage compartments. Generally the tank volume is partially filled with a liquid product, the remaining part of the volume being filled with ambient air. This ambient air will saturate with vapour resulting from the liquid, until the vapour pressure, corresponding to the temperature in the tank, is reached. Furthermore evaporation is determined by the so-called breathing of the tank, whereby saturated vapour is discharged out of the tank and clean air from outside is drawn in into the tank. While filling this type of storage tanks containing liquid products, the air present in the tank, comprising vapour from the liquid, will be vented from the tank and emitted to the ambient air, unless suctioned in and recycled.

25 The "floating roof" storage tanks have a variable volume. The roof of the tank floats upon the liquid contained in the tank, so that usually, as a result, no free space is present within this type of tank. When the liquid is pumped out of the tank, the roof will move down until it reaches a mechanically determined minimum height; usually about 1,5 meter above the base floor of the tank, whereby the roof is supported upon legs mounted onto the underside the roof. When the tank is further drained, the free space between the roof, supported on its legs, and the liquid is filled with ambient air. This air will also get saturated with vapour resulting from the liquid until the vapour pressure, corresponding to the temperature in the tank, is reached. While the tank is refilled with the liquid product, the air, saturated with vapour, will be vented to atmosphere outside of the tank through the so-called "rim seals". This vapour-air mixture generally has a higher specific weight than ambient air and remains therefore usually within the cylindrically shaped upright wall, which e.g. may lead to so-called

"rim fires": fires originating from lightning strokes on the tank, thereby causing ignition of said vapour-air mixture.

Besides vapour-phase emissions also emissions of the liquid products from both type
5 of tanks may occur. Generally these emissions are caused by small scale leakages like
e.g. not thoroughly closed flanged connections or leaking valves. The liquid losses
caused by small leakages generally disappear into the base ground nearby the tank.
Large losses will occur as a result of the failure of the wall of the tank. Each tank is
therefore surrounded by a so-called "bundwall". This is a dike around the tank,
10 whereby the height of the dike and the interior surface are such dimensioned in that
the holding capacity for the amount of liquid corresponds to the maximum tank
volume. Finally, subsequent to pumping the major part of the liquid out of the tank,
the remaining liquids are lost during cleaning of the tank.

15 From DE 10 2004 009398 and US 3,537,608 is it is known to store liquids into
compartments of flexible liquid holders, so that cleaning of the storage tank is not
necessary when changing the stored liquid and so that vapour formation in the free
space is reduced. However, within these flexible liquid holders a gas or vapour phase
is formed, for example by evaporation of liquid or gas expelled from the liquid, like
20 with partially degassed crude oil extracted from bored wells. Due to this effect the
flexible liquid holder is further inflated by the gas or the vapour phase, so that after
draining the liquid holder by removal of the liquid phase, a substantial amount of gas
or vapour is retained within the flexible holder which may contaminate the next liquid
charge or may lead to undesired emissions and/or loss of product or to costs for
25 cleaning.

Moreover the presence of (large) amounts of inflammable vapours and gasses is
undesirable because of the danger of fire or explosion.

From Dutch Patent 1030882 in the name of the applicant, an inflatable element is
30 known (also indicated as airbag) for use interiorly in a holder, the holder being
suitable for storing and/or transporting of a liquid load, in particular for a holder of a
transport or storage device like a tank lorry, a tank container or a storage tank. The
inflatable element may be adjusted to the free space above the liquid in the holder, so
that both an anti-slosh device and a reduction of the vapour space is realized.

35 Therefore there is a need for a system whereby continuously and reliably, at low
costs, with a considerable reduced risk of fire or explosion, with a minimum chance on

failure and without any effect upon the quality of the stored liquid, the storage tank may be operated in such a way that vapour or gas formation in the liquid holders, located inside the storage tank, is avoided.

5 The object of the invention is therefore to provide a system whereby vapour and gas formation by liquids present in the tank, vapour and gas emissions to the environment and also uncontrollably and undesirably expelling of liquids from the tank during filling and emptying is prevented, and whereby the risk of fire and/or an explosion is reduced and a dike or 'bundwall' is superfluous for retaining the liquid
10 product or liquid load in case of failure of the storage tank wall or of failure of the holder of the liquid products.

This object of the invention is achieved by a system according to the preamble; the system further comprises: at least one inflatable element, suitable for containing an
15 inflating gas.

By combining the liquid load in the liquid holder with an inflatable element the gas and vapour formation is reduced, formation of a gas or vapour phase in the liquid holder is prevented as a result of inflating the inflatable element by means of the inflating gas.

20 In a preferred embodiment the inflatable element is provided with an accordion wall or otherwise extendable or unfoldable wall or walls, which unfold or fold up respectively by supplying or discharging inflating gas.

These measures allow for the volume of inflatable element to be varied easily without the need of applying a high pressure within the inflatable element.

25 Preferably the flexible liquid holder comprises flexible walls and/or is provided with an accordion wall or otherwise extendable or unfoldable wall or walls, which unfold or fold up respectively by supplying or discharging the liquid load.

These measures enable that the volume of the liquid holder may be varied easily
30 without the need of bringing the liquid load to a high pressure.

Particularly the inflatable element and/or the liquid holder are configured out of two or more elements or are provided with two or more compartments.

As a result thereof large elements or holders for large storage tanks may be
35 manufactured easily and at low costs.

The invention also provides for an inflatable support element provided interiorly within the liquid holder, which support element, in its inflated use position, being suitable as support for the roof of the storage tank or as support for the inflatable element.

- 5 These inflatable support elements, provided inside the liquid holder, occupy a portion of the liquid holder so that the roof or an inflatable element located upon the liquid holder, may be supported and inflow of ambient air is prevented or strongly reduced.

10 In an alternative embodiment the liquid holder, positioned within the storage tank, on its upper side is not provided with a wall, so that as a result the inflatable element rests upon the liquid surface of the liquid load.

In this embodiment of the liquid holder, being open at the upper side and whereby the upper side is covered by the inflatable element, the free space above the liquid – and therewith the formation of vapour and gas – is reduced by the inflatable element.

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In particular means are provided for adapting the volume of the inflatable element and/or the support element when the volume of the flexible liquid holder changes.

20 Preferably the means are selected from: vacuum en overpressure means; a pressure or level controlled air system with air pump or compressor or other overpressure air system; safety, warning or registration system for liquid present between the flexible liquid holder and the wall of the storage tank.

25 Therewith the formation of vapour and gas in the liquid holder is decreased and vapour emissions and uncontrollable and undesirable expelling of liquids from the storage tank, during filling and draining, is prevented.

Particularly the roof of the storage tank is a floating roof, and that the inflatable element, at its roof side, is provided with a shape corresponding to the interior shape of the roof.

30 Preferably the inflatable element, with the therein contained inflating gas, is mounted upon the upper side of the flexible liquid holder such that in the use position within the storage tank essentially the inflatable element abuts against the roof of the holder and the flexible liquid holder essentially abuts against the base of the storage tank.

35 The inflatable elements closely adjacently link up against the roof in order to prevent vapour and gas formation, while the liquid holder closely abuts against the base preventing emission and leakage of liquid.

In an alternative embodiment the inflatable element and the flexible liquid holder each are provided with connection means, such as inflow en outflow means, with which inflating gas and liquid load respectively, without contacting the storage tank or the tank wall, are supplied in or out of the storage tank.

In particular the inflatable element only occupies a portion of the volume difference between the volume of the storage tank and the volume of the liquid holder.

By means of the connection means the liquid holder and the inflatable element may be filled and drained independently with respect to each other.

As a result, if required, the system may be operated in such a way, that the liquid holder and the inflatable element together will not completely fill up the entire volume of the storage tank.

The invention also relates to a method for supplying and discharging of liquid load to a storage tank which is provided with a system according to the invention comprising the following steps:

- supplying and discharging of liquid load to the flexible liquid holder such that the volume changes of the liquid holder,
- registration of the volume change of the liquid holder,
- supplying and discharging inflating gas into the inflatable element, such that the volume change in the liquid holder is compensated.

In particular the method further comprising the following step:
supplying or discharging of inflating gas into of from the inflatable element and/of the inflatable support element for displacing the roof of the storage tank.

The invention also provides for an optional addition, which measures, registers or reports the possible presence of liquid between the flexible liquid holder and the tank wall. This addition may optionally be connected to a safety or warning system of the tank terminal, where the storage tank is a part of.

The invention also provides for the possibility to let the upper side of the inflatable element function as the roof of the tank, such that this upper side of the inflatable element is always retained at the same position, identical to the roof of a "fixed roof" tank and in which the remaining part of the inflatable element is adaptable to a variety

of shapes so that free air is not available in the tank, or in other words, the entire volume of the tank is filled by the liquid and the inflatable element.

5 The invention takes care for both considerably decreasing the possibility of the creation and the consequences of a fire or an explosion and for an alternative configuration during a catastrophe with two independently functioning flexible holders within the storage tank: an inflatable element and a liquid holder, whereby the current storage tank outside wall constitutes the outer boundary. As a result it is possible to build and operate the storage tanks closer to each other in a safe way thereby using
10 less ground for the storage of a certain amount of liquid.

The invention is further explained by means of a drawing and some embodiments of the method and system having an inflatable element and the flexible liquid holder whereby features and other advantages will come forward.

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Fig. 1 shows a perspective view of a storage tank having a "floating roof", provided with a system according to the invention,
Fig. 2 shows a perspective view of a storage tank with a "fixed roof" provided with the system according to the invention,
20 Fig. 3 shows a perspective view of an "open" storage tank provided with the system according to the invention.

Figure 1 shows a storage tank 2 with a roof 6, which may vertically displace within the storage tank (floating roof), provided with inflatable support elements 10 within the liquid holder 1. On the right side of the storage tank 2 is shown liquid holder 1 wherein liquid load 3 is contained. The liquid holder 1 may be provided with a flexible wall 8 and/of an accordion wall 7 or otherwise extendable or unfoldable wall so that the volume of the liquid holder may be easily, without the need of applying a high internal pressure, be enlarged or made smaller when the liquid load 3 is introduced
25 into or out of the liquid holder, respectively. When the storage tank 2 empties, the roof 6 will move downwards. In order to prevent that the roof 6 will rest upon the ground base 16 of the storage tank 2 and in order to reduce the free space within the liquid holder, inflatable support elements 10 are provided within the liquid holder 1. In the left part of the storage tank 2 in Fig.1 the liquid holder 1 is omitted so that the inflatable support elements 10 are visible as support of the roof 6. The inflatable support elements 10 may also be used as support for an inflatable element 11 (see
30 Fig.2) which is mounted on top of the liquid holder 1.

Figure 2 shows a storage tank 2, having a roof 6' which cannot be vertically displaced within the storage tank (fixed roof), provided with an inflatable element 11 and a liquid holder 1 according to the invention. In this embodiment the liquid holder 1 may be open on its upper side or constitute a completely enclosed space. Both the liquid holder 1 and the inflatable element 11 may be provided with an accordion wall 7 respectively 12. The inflatable element 11 and/or the liquid holder 1 may each comprise one space, but may also be formed from two or more elements and/or be provided with two or more compartments. In order to prevent formation of vapour or gas within the storage tank 2 and/or within the liquid holder 1, the inflatable element 11 and the liquid holder 1 together are exactly filling up the internal volume of the storage tank 2. When the liquid load 3 is introduced into the liquid holder or when gas or vapour formation occurs in the liquid holder 1, the volume of the liquid holder will increase so that as a result the volume of the inflatable element 11 must decrease and consequently the amount of inflating gas 13 must be reduced. When liquid load 3 is removed from the liquid holder 1 or the amount of vapour or gas within the liquid holder 1 decreases, the volume of the inflating gas 13 within the inflatable element 11 consequently must be increased. Therefore for compensation, the system according to the invention provides for means by which the volume of the inflatable element 11 may be changed oppositely, when the volume of the flexible liquid holder 1 changes. These means may be a warning or registration system, whereby for example the pressure in the liquid holder 1 and/or the inflating element 11 is measured. Other suitable measurement methods are: a level measurement or a weight measurement of the liquid load or a pressure measurement of the walls with a resistance strain gauge or similar. Furthermore a flow-measurement may be provided at the connection means 9, 17. After the volume change of the liquid holder 1 is measured and/or registered, the control part of the system will charge or discharge inflating gas 13 to or from the inflatable element 11, such that the volume change within the liquid holder will be compensated. The charging or discharging may be executed by means of a feedback loop, but may also be executed by means of a calculation of a certain amount of required volume. Because of the explosion, safety and vapour requirements, the control part of the system may be set up in such a way, that the volume of the storage tank 2 is continuously completely filled up, but if required may also be set up, such that the liquid holder 1 and the inflatable element 11 only occupy a portion of the volume of the storage tank 2. The system may comprise vacuum or overpressure facilities and an air system comprising an air pump or compressor 15.

In a preferred embodiment the inflatable element 11 on its upper or roof side is provided with a shape corresponding to the interior shape of the roof. In Fig.2 both

the roof 6' and the inflatable element 11 are provided with a conical shape. As a result the inflatable element 11 closely links up with the roof 6' so that deformation of the inflatable element 11 or creation of free spaces between the inflatable element 11 and the roof 6' is prevented. The corresponding shape of a roof 6 (like in Fig.1) has the advantageous effect of a uniform distribution of the forces acting upon the roof, so that the inflatable element 11 has a small chance on deformation and/or leakage and moreover the roof will be uniformly supported over its entire surface and can be moved vertically.

The liquid holder 1 in Fig.2 may be open at its upper side, so that the inflatable element 11 rests upon or is supported by the liquid surface of the liquid load 3. The liquid holder rests upon or is supported by the base ground 16 of the holder 2. Because the inflatable element 11 is in contact with the liquid load 3 the vapour and gas formation above the liquid is prevented. Preferably the liquid holder 1 is a completely enclosed space so that as a result the liquid load 3 does not come in contact with the walls of the storage tank 2 and the walls of the inflatable element 11 so that contamination of the inflatable element 11 and/or the walls may not occur.

Preferably the system is provided with a supply system 15, 17 for a gaseous product (also inflating gas 13), usually ambient air, which is available at the storage tank 2 location by means of an air or gaseous supply system, or otherwise by means of a facility directly coupled with inflating element 11 like an air or gas compressor or pump 15 or a high pressure storage vessel. The supply system consists of a discharge system for the gaseous product comprising a direct exhaust facility when applying ambient air or comprising a system wherein cleaning facilities or other possibilities are provided for reuse or another responsible method for removal of the gaseous product. In its basic configuration the system is pressure controlled. When filling the storage tank 2 or the holder with the liquid load 3 by means of connection 9 the pressure within the inflatable element 11 will rise so that the pressure controlled system, comprising the inflatable element 11, will discharge gaseous filling out of the inflatable element 11 by means of connection 17 in such a way that the otherwise resulting pressure increase is neutralised. During the removal of liquid load 3 from the storage tank 2 or from the holder of the liquid load 3, the pressure within the inflatable element 11 will decrease so that the pressure controlled system, comprising the inflatable system 11, will supply gaseous product into the inflatable element 11 in such a way that the otherwise resulting pressure drop is counter acted and neutralized. In case of a gas or vapour formation in the liquid holder 1 the pressure within the inflatable element – for the reduction of the formation of this vapour or gas formation – is set up at a small overpressure, for example between 0 – 1 bar

overpressure and preferably the pressure is selected from the range 0 – 0.2 bar overpressure.

Figure 3 shows a storage tank 2 without roof having an inflatable element 11. In this embodiment the inflatable element 11 functions as the roof of the 'open' storage tank 2. With an "open" liquid holder 1 the bottom side 18 of the inflatable element rests upon the liquid surface of the liquid load 3. In a preferred embodiment a closed liquid holder 1 is provided whereby the bottom side of the inflatable element also rests upon the upper side of the liquid holder 1.

The inflatable element of the liquid holder may be manufactured from (a combination of) a suitable material like a plastic or metal.

The storage tank may be positioned upon a solid base ground, but may also be part of a floating object like a tanker or a floating storage tank.

CLAIMS

1. System for use interiorly in a storage tank (2) suitable for storing a liquid load (3), the system comprising:
 - at least one flexible liquid holder (1) for containing the liquid load (3),
 - at least one inflatable element (11), suitable for containing an inflating gas (13),wherein the inflatable element (11), with the therein contained inflating gas (13), is mounted upon the upper side of the flexible liquid holder (1),
characterized in that
 - the inflatable element (11) is provided with connection means (9) with which inflating gas (13) is supplied in or out of the inflatable element (11) and the flexible liquid holder (3) is provided with connection means (17) with which liquid load (3) is supplied in or out of the flexible liquid holder (3);
 - the inflatable element (11) is provided with an accordion wall (12) or otherwise extendable or unfoldable wall or walls, which unfold or fold up respectively by supplying or discharging inflating gas (13) so that in use the volume of the inflatable element (11) may be varied to compensate for changes in volume of the liquid holder (1);
 - and in that the flexible liquid holder (1) is provided with an accordion wall (7) or otherwise extendable or unfoldable wall or walls, which unfolds or folds up respectively by supplying or discharging the liquid load (3);
 - means are provided for adapting the volume of the inflatable element (11) when the volume of the flexible liquid holder (1) changes.
2. System according to claim 1, **characterized in that** the means for adapting the volume of the inflatable element (3) are selected from: vacuum and overpressure means; a pressure or level controlled air system with air pump or compressor (15) or other overpressure air system; safety, warning or registration system for liquid present between the flexible liquid holder and the wall of the storage tank.
3. System according to anyone of the preceding claims 1 - 2, **characterized in that**, the inflatable element (11) and/or the liquid holder (1) are configured out of two or more elements or are provided with two or more compartments.
4. System according to anyone of the preceding claims 1 - 3, **characterized in that** an inflatable support element (10) is provided interiorly within the liquid holder (1), which

support element (10), in its inflated use position, being suitable as support for the roof (6) of the storage tank (2) or as support for the inflatable element (11).

5. System according to claim 4, **characterized in that** means are provided for adapting the volume of the support element (10) when the volume of the flexible liquid holder (1) changes.
6. System according to anyone of the preceding claims 4 - 5, **characterized in that** the system is adapted for use in a storage tank (2) having a floating roof (6), wherein the inflatable element (11), at its upper roof side, is provided with a shape corresponding to the interior shape of the roof (6) of the storage tank (2).
7. Method for supplying and discharging of liquid load (3) to a system for use interiorly in a storage tank (2) according to anyone of the preceding claims 1 - 6 comprising the following steps:
 - supplying and discharging of liquid load (3) to the flexible liquid holder (1) such that the volume of the liquid holder (1) changes,
 - registration of the volume change of the liquid holder (1),
 - supplying and discharging inflating gas (13) into the inflatable element (11), such that the volume change in the liquid holder (1) is compensated.