

DESCRIPTION

TITLE: STORAGE SYSTEM AND METHOD FOR STORING FLUIDS COMPRISING A VENTILATION DEVICE

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Technical field

10 The present invention relates to underground storage and notably to the storage of fluids, for example hydrogen or oxygen. More particularly, the invention relates to the field of ventilation in a fluid storage system and, in particular, in a high-pressure fluid storage system, which may be at between 100 bar and 1200 bar, and more particularly between 200 bar and 500 bar.

15 The invention also relates to an underground fluid storage method.

Technological background

20 In an underground fluid storage system, the risk of fluid leaks has to be taken into account, particularly if the fluid is explosive. To mitigate this risk, ventilation is an essential aspect to be taken into account. Specifically, in the event of a leak, ventilation prevents the product from accumulating in the storage system and increasing in pressure. Ventilation thus dilutes the proportion of the fluid in the air, obviating the risk of explosion.

25 Certain ventilation devices that are monitored by leak detectors in fluid storage systems are currently known. Generally, this type of ventilation requires a mechanical and/or electrical source to operate correctly, and therefore has to be monitored. In the event of a fault, maintenance operations are necessary.

Disclosure of the invention

30 The aim of the invention is to overcome the aforementioned problems by proposing a reliable, standalone solution not liable to failure or maintenance problems.

35 The invention relates to an underground storage system for storing fluids. The system comprises a hole in a plot of land, said hole having a bottom, a support element

comprising at least one opening, a joining element inserted into the opening in the support element, a ventilation device comprising at least one ventilation cavity, at least one reservoir, said reservoir having a longitudinal axis, a lower end closed by a first closure means, and an upper end closed by a second closure means. The upper end is
 5 joined to the support element via the joining element such that the reservoir is suspended inside the hole and such that an axial clearance able to absorb any axial thermal expansion of said reservoir remains between the first closure means of the reservoir and the bottom of the hole.

Advantageously, the ventilation cavity is hollowed out of the plot of land and
 10 is adjacent to the hole.

The ventilation cavity comprises an entrance, a means for accessing the ventilation cavity, and an opening made between the hole and the ventilation cavity.

According to one embodiment, the ventilation device comprises at least one deflector.

15 Advantageously, the deflector is made of aluminum.

Optionally, the deflector is positioned at the entrance to the ventilation cavity, enabling part of the wind to be directed into the ventilation cavity.

Optionally, the deflector is positioned at the entrance to the hole, enabling part of the wind to be directed into the hole.

20 Advantageously, the reservoir comprises at least one metal tube, said metal tube having at least one end provided with at least one threaded portion.

The reservoir comprises at least two metal tubes screwed together, so as to form a column of tubes.

Advantageously, the axial clearance capable of absorbing any axial thermal
 25 expansion of the reservoir satisfies the following inequality:

[Math 1]

$$G \geq (L^2 * \beta * \alpha) + [20 * \alpha * 80 * (1 - e^{-0.11*L})]$$

Where: G is the length of the axial clearance expressed in meters, L represents the length of a reservoir expressed in meters, β represents the geothermal gradient expressed in degrees Celsius per meter, and α represents the coefficient of thermal
 30 expansion of the metal expressed in meters per degree Celsius.

According to one embodiment, the storage system comprises a plurality of reservoirs, each reservoir having a longitudinal axis, a lower end and an upper end,

said upper end of each reservoir being joinable to the support element via a joining element such that each reservoir is suspended inside the hole.

Optionally, the first closure means and/or the second closure means is able to close the reservoir by screw-fastening.

5 Advantageously, the hole comprises at least one lining, said lining being made of concrete, cement or steel.

The invention also relates to an underground storage method for storing fluids using a storage system as described above. The method includes at least the following steps:

- 10 - making a hole in a plot of land, said hole having a bottom,
- providing a support element comprising at least one opening able to receive a joining element,
- providing a ventilation device comprising at least one ventilation cavity,
- providing at least one reservoir, said reservoir having a longitudinal axis, a lower end and an upper end,
- 15 - providing a first closure means able to close said reservoir at its lower end, and a second closure means able to close the reservoir at its upper end,
- joining said upper end to the support element via the joining element such that the reservoir is suspended inside the hole and such that an axial clearance able to absorb any axial thermal expansion of said reservoir remains between the
- 20 first closure means of the reservoir and the bottom of the hole.

Definitions

25 The “lower end” of the reservoir is understood to be that end of the reservoir that is in the vicinity of the bottom of the hole. This “lower end” is defined in contrast to the end referred to as “upper end” of the reservoir, which is in the vicinity of the support element and therefore the surface of the ground.

30 “Axial clearance” is understood to be a length which extends along the longitudinal axis of the reservoir and is measured between the first closure means of the reservoir, which is proximal to the bottom of the hole, and said bottom of the hole. It should be noted that the position of a reservoir does not have to be perfectly vertical. In this case, the longitudinal axis of the reservoir is at an angle in relation to the vertical

in the frame of reference (x; y). This angle has a maximum value of 15°. In this case, the axial clearance is measured by orthogonal projection onto the vertical axis passing through a point on the first closure means that is closest to the bottom of the hole. In other words, the axial clearance always corresponds to the shortest distance, measured
 5 between the bottom of the hole and the first closure means.

A “threaded metal tube” is understood to be a tube comprising at least one end having at least one threaded portion, able to be joined to a threaded metal tube comprising at least one end having at least one complementary threaded portion. The thread may be male or female.

10 The “bottom of the hole” is understood to be the surface of the bottom of the hole. Thus, when the hole is lined and said lining is cemented, the expression “bottom of the hole” then denotes the surface of the layer of cement at the bottom of the hole. If the lining is not cemented, the term “bottom of the hole” very simply denotes the surface of the plot of land at the bottom of the hole.

15 “Ventilation cavity” is understood to be an empty space in a solid body, said space being passable by the wind in order to ventilate the storage system. The ventilation cavity is designed to renew the air inside the storage system.

20 *Brief description of the drawings*

Other aims, features and advantages of the invention will become apparent on reading the following description, given solely by way of non-limiting example and made with reference to the appended drawings in which:

25 - [Fig. 1] is a schematic view of the general structure of an underground storage system;

- [Fig. 2] is a schematic view of the ventilation device of an underground storage system;

30 - [Fig. 3] is a schematic view showing the deflector and its projected area, in a ventilation device of an underground storage system;

- [Fig. 4] is a schematic top view of a first embodiment of the ventilation device of an underground storage system; and

- [Fig. 5] is a schematic top view of a second embodiment of the ventilation device of an underground storage system.

Detailed description

5 Figure 1 illustrates a sectional view of a storage system 1 according to one embodiment of the invention, in a coordinate system (x; y). The axis x of the coordinate system (x; y) is a horizontal axis, and the axis y of the coordinate system (x; y) is a vertical axis.

10 The storage system 1 comprises a hole 2 made in a plot of land 3, a ventilation device 4, a support element 5 placed on a surface of a ground S of the plot of land 3, and seven reservoirs 6 suspended from the support element 5 in the hole 2 (only four reservoirs 6 are visible in figure 1). In various embodiments, the storage system 1 generally comprises at least one reservoir 6.

15 The hole 2 has a bottom 7 and comprises a lining 8. The hole 2 may be obtained by boring or by excavating. The hole 2 is of substantially circular cylindrical shape and has a mean diameter of four meters.

 The lining 8 is made of cement and extends vertically from the ground surface S to the bottom 7 of the hole 2.

20 Figure 2 illustrates the ventilation device comprising a ventilation cavity 9. Ventilation of such a storage system 1 is necessary to reduce the risk of explosion or fire that could cause a leak in a reservoir 6.

 The flow of air in the upper portion of the hole 2 is brought about by the temperature difference and buoyancy of the air. The following equation describes this phenomenon:

25 [Math 2]

$$Q = Cd * Ae * \sqrt{\frac{4 * \Delta T}{(Tin + Tout)}} g * H$$

30 Where Q is the ventilation flow rate, Cd is the coefficient of expansion, Ae is the effective area of the natural ventilation opening, ΔT is the difference between the temperature of the hole and the outside temperature, Tin is the temperature of the hole, Tout is the outside temperature, g is gravity and H is the distance between the openings.

 If the temperature Tin of the hole is equal to the outside temperature Tout, the difference ΔT is zero and thus ventilation is not effective.

To guarantee ventilation, a ventilation cavity 9 adjacent to the hole 2 is created to generate a third temperature T_c that represents the temperature of the ventilation cavity 9. Since the depth of the ventilation cavity 9 is different from the depth of the hole 2, the temperatures T_{in} , T_c are different. Specifically, for example, the following is true with a geothermal gradient of 3°C per 100 m:

[Math 3]

$$Gt * DS - Gt * DA \geq 0.3^{\circ}\text{C}$$

Where Gt is the geothermal gradient ($0.03^{\circ}\text{C}/\text{m}$), DS is the depth of the hole 2 in meters, and DA is the depth of the ventilation cavity 9 in meters.

The ventilation device 4 therefore comprises at least one ventilation cavity 9 hollowed out of the plot of land 3 and adjacent to the hole 2.

The ventilation cavity 9 is used to create natural ventilation formed by air flows from the ventilation cavity 9 to the hole 2 and vice versa.

The ventilation cavity 9 comprises an entrance 10, a means 11 for accessing the ventilation cavity 9, and an opening 12 made between the hole 2 and the ventilation cavity 9. The means 11 for accessing the cavity may be a staircase or a ladder. The opening 12 between the hole 2 and the ventilation cavity 9 may for example be a corridor or a grating door.

Preferably, an empty space enables ventilation above the support element 5. This embodiment is illustrated in figure 2 in which no component blocks the free circulation of the air above the reservoirs 6. For safety reasons, a grating 20 (see figure 1) may be provided, but in any case natural or forced ventilation must be able to flow freely through the ventilation cavity 9 in a direction from the zone located above the support element 5 toward the entrance to the cavity 10 or in the opposite direction.

Advantageously, the ventilation device 4 also comprises a deflector D used to promote natural ventilation installed with the ventilation cavity 9. Of course, the ventilation device 4 may comprise several deflectors D.

The deflector D may be made in various shapes and of various materials such as steel, plastic or aluminum.

It can be positioned at the entrance 10 to the ventilation cavity 9 so as to direct a portion of the wind into the ventilation cavity 9, and it can be positioned at the entrance to the hole 2 so as to direct a portion of the wind into the hole 2.

The deflector D is used to direct the wind that it receives toward the inside of the ventilation cavity 9. The wind therefore flows from the ventilation cavity 9 toward the hole 2 via the opening 12, thus ventilating the storage system 1.

The following equation represents the ventilation induced by the wind:

5 [Math 4]

$$Q = Cd * Ae * \mu_w * \sqrt{\Delta Cp}$$

Where μ_w is the wind speed and ΔCp is the pressure coefficient of the building.

10 Optimization of the ventilation flow rate Q delivered depends on the area Ae which corresponds to the projected area (a x b) of the deflector D, illustrated in figure 3. The area a x b corresponds to a plane perpendicular to the axis x. The deflector D illustrated in figure 3 comprises a rectangular projected area Ae which is equal to the height a times the width b.

The dimensions of the area Ae are calculated using the following equation:

15 [Math 5]

$$Ae = \frac{Q}{Cd * \mu_w * \sqrt{\Delta Cp}}$$

For example, a ventilation flow rate Q of 0.3 m³/s, a coefficient of expansion Cd of 0.5, a wind speed μ_w of 0.28 m/s and a coefficient ΔCp of 0.5 provide a projected area Ae of the deflector D of 3.03 m².

20 According to a first embodiment illustrated in figure 4, the ventilation device 4 comprises a ventilation cavity 9 adjacent to the hole 2 and four deflectors D1, D2, D3, D4. The deflectors D1, D2 are positioned at the entrance to the ventilation cavity, and the deflectors D3, D4 are positioned at the entrance to the hole.

25 This installation allows the deflectors D1, D2 positioned at the entrance to the ventilation cavity to catch the wind V1 coming from the north N and the east E and to direct it toward the inside of the ventilation cavity 9. The wind V1 thus creates an air flow from the ventilation cavity 9 toward the hole 2 via the opening 12 located between the ventilation cavity 9 and the hole 2.

30 In the same way, the deflectors D3, D4 positioned at the entrance to the hole catch the wind V2 coming from the south S and the west W and direct it toward the inside of the hole 2. The wind V2 thus creates an air flow from the hole 2 to the ventilation cavity 9 via the opening 12 located between the ventilation cavity 9 and the hole 2.

According to a second embodiment illustrated in figure 5, the ventilation device 4 comprises two ventilation cavities 9, 13 adjacent to the hole 2 and four deflectors D5, D6, D7, D8. The deflectors D5, D6 are positioned at the entrance to the first ventilation cavity 9, and the deflectors D7, D8 are positioned at the entrance to the second ventilation cavity 13.

This installation allows the deflectors D5, D6 positioned at the entrance to the first ventilation cavity 9 to catch the wind V1 coming in this case from the north N and the east E and to direct it toward the inside of the first ventilation cavity 9. The wind V1 thus creates an air flow from the first ventilation cavity 9 toward the hole 2 via the opening 12 located between the first ventilation cavity 9 and the hole 2.

In the same way, the deflectors D7, D8 positioned at the entrance to the second ventilation cavity 13 catch the wind V2 coming in this case from the south S and the west W and direct it toward the inside of the second ventilation cavity 13. The wind V2 thus creates an air flow from the second ventilation cavity 13 to the hole 2 via the opening 12 located between the second ventilation cavity 13 and the hole 2.

Thus, an installation is made to provide an optimal ventilation device 4 in consideration of requirements.

The support element 5 is a circular cylindrical plate having a central body and a flange, said flange having a lower surface resting on the ground S. The support element 5 further comprises an upper surface, said upper surface being opposite the lower surface of the flange. The support element 5 also comprises seven openings. The openings are through-holes made in the first thickness of the body of the support element 5. The support element 5 comprises at least one opening.

As shown in figure 1, each reservoir 6 is suspended from the support element 5 via a joining element. The reservoirs 6 are tubular, with a circular cross section, and each have a longitudinal axis, a lower end 14 closed by a first closure means 15, and an upper end 16 closed by a second closure means 17. Thus, for each reservoir 6 of the storage system 1, an axial clearance G remains between the first closure means 15 and the bottom 3 of the hole 2.

The purpose of this axial clearance G is to absorb any axial thermal expansion of the reservoir 6, which occurs notably during filling and emptying operations. Thus, for each reservoir 6, the dimensioning of the axial clearance G, and notably its length, depends directly on the conditions of the surrounding area of the storage system 1, notably conditions regarding temperature, pressure and the ability of the reservoir 6 to

expand when it is subjected to temperature and pressure variations, notably during filling and emptying operations. Thus, the axial clearance G of any reservoir 6 of the storage system 1 satisfies the following inequality:

[Math 1]

$$G \geq (L^2 * \beta * \alpha) + [20 * \alpha * 80 * (1 - e^{-0.11*L})]$$

Where: G is the length of the axial clearance expressed in meters. L represents the length of a reservoir 6 expressed in meters. β represents the geothermal gradient expressed in degrees Celsius per meter. The geothermal gradient β varies depending on the geological formation in which the storage system 1 is placed. Thus, β is such that $0.02^\circ/\text{m} \leq \beta \leq 2^\circ/\text{m}$. α represents the coefficient of thermal expansion of the metal expressed in degrees Celsius-1. The coefficient of thermal expansion α varies depending on the type of metal from which the tubes used to form a reservoir 6 are made. Thus, α is such that $8*10^{-6} \text{ }^\circ\text{C}^{-1} \leq \alpha \leq 18*10^{-6} \text{ }^\circ\text{C}^{-1}$.

In the embodiment illustrated in figure 1, the lower end 14 and the upper end 16 of each reservoir 6 are threaded ends, and the first closure means 15 and the second closure means 17 also have a thread, said thread complementing the thread of the lower end 14 and of the upper end 16. As a result, the lower end 14 is sealingly closed by screw-fastening with the first closure means 15, and the upper end 16 is sealingly closed by screw-fastening with the second closure means 17.

The second closure means 17 is fitted with sensors 18, such as pressure gauges, thermometers and leak detectors. Of course, the first closure means 15 may also contain pressure gauges, thermometers and leak detectors. Other types of sensors can be used depending on the nature of the parameters to be monitored.

Each reservoir 6 may comprise a plurality of tubes A. In the embodiment illustrated in figure 1, the reservoirs 6 comprise multiple threaded tubes A. Thus, the tubes A are screwed to one another so as to form a column C of tubes A. In this way, each reservoir 6 is formed by an assembly composed of a column C, closed at its ends 14, 16 by closure means 15, 17. A reservoir 6 may also be composed of a single tube A, closed at its ends 14, 16 by closure means 15, 17.

The storage system also comprises one joining element 19 per reservoir 6. Each joining element 19 is inserted into an opening of the support element 5 and held by a flange which abuts against the upper surface of the support element 5. Each joining element 19 is thus suspended from the support element 5. In this way, each reservoir 6 is suspended from the support element 5 via the joining element 19 to which it is joined.

A joining element 19 is a tubular metal part of circular cross section which comprises a tubular body and a flange.

5 The body of the joining element 19 is fastened to the upper end 16 of a reservoir 6, preferably by screwing. The body of the joining element 19 includes a male or female thread (not shown) complementary to the thread of the upper end 16 of the reservoir 6 to which said joining element 19 is joined. The flange of the joining element 19 comprises an upper surface and a lower surface. In a variant, the body of the joining element may be fastened by welding.

10 In the embodiment illustrated in figure 1, the tubular body of each joining element 19 is inserted into an opening in the support element 5. Each joining element 19 rests on the support element 5 via its lower surface bearing against the upper surface of the support element 5. In addition, each joining element 19 is joined to a reservoir 6 by screwing at the upper end 16 of said reservoir 6.

15 The flange therefore enables the joining element 19 to rest on the upper surface of the support element 5. As a result, the joining element 19 does not need to be fastened to the support element 5, for example by welding or by screwing, thereby simplifying assembly of the storage system 1, notably in order to suspend the reservoirs 6.

20 The storage system 1 can be used to store any type of fluid, in particular explosive gases. The fluid can be hydrogen, oxygen, methane, nitrogen, ammonia, the fluid preferably being hydrogen.

25 The invention also provides an underground storage method for storing fluids using a storage system 1 as described above. The method includes at least a step of making a hole 2 in a plot of land 3, said hole 2 having a bottom 7, a step of providing a support element 5 comprising at least one opening able to receive a joining element 19, a step of providing a ventilation device 4 comprising at least one ventilation cavity 9 as described above, a step of providing at least one reservoir 6, said reservoir 6 having a longitudinal axis, a lower end 14 and an upper end 16, a step of providing a first closure means 15 able to close said reservoir 6 at its lower end 14, and a second closure means 17 able to close the reservoir 6 at its upper end 16, and a step of joining said upper end 16 to the support element 5 via the joining element 19 such that the reservoir 6 is suspended inside the hole 2 and such that an axial clearance G able to absorb any axial thermal expansion of said reservoir 6 remains between the first closure means 15 of the reservoir 6 and the bottom 7 of the hole 2.

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CLAIMS

5 1. An underground storage system (1) for storing fluids, characterized in that said system (1) comprises:

- a hole (2) made in a plot of land (3), said hole (2) having a bottom (7),
- a support element (5) comprising at least one opening,
- a joining element (19) inserted into the opening of the support element (5),
- a ventilation device (4) comprising at least one ventilation cavity (9),
- 10 - at least one reservoir (6), said reservoir (6) having a longitudinal axis, a lower end (14) closed by a first closure means (15), and an upper end (16) closed by a second closure means (17),
said upper end (16) being joined to the support element (5) via the joining element (19) such that the reservoir (6) is suspended inside the hole (2) and such that an
15 axial clearance (G) able to absorb any axial thermal expansion of said reservoir (6) remains between the first closure means (15) of the reservoir (6) and the bottom (7) of the hole (2).

20 2. The storage system (1) as claimed in claim 1, wherein the ventilation cavity (9) is hollowed out of the plot of land (3) and is adjacent to the hole (2).

20 3. The storage system (1) as claimed in one of claims 1 and 2, wherein the ventilation cavity (9) comprises an entrance (10), a means (11) for accessing the ventilation cavity (9), and an opening (12) made between the hole (2) and the ventilation cavity (9).

25 4. The storage system (1) as claimed in any one of claims 1 to 3, wherein the ventilation device (4) comprises at least one deflector (D).

 5. The storage system (1) as claimed in claim 4, wherein the deflector (D) is made of aluminum.

30 6. The storage system (1) as claimed in one of claims 4 and 5, wherein the deflector (D) is positioned at the entrance (10) to the ventilation cavity (9), enabling part of the wind to be directed into the ventilation cavity (9).

 7. The storage system (1) as claimed in either one of claims 4 and 5, wherein the deflector (D) is positioned at the entrance to the hole (2), enabling part of the wind to be directed into the hole (2).

8. The storage system (1) as claimed in any one of claims 1 to 7, wherein the reservoir (6) comprises at least one metal tube (A), said metal tube (A) having at least one end provided with at least one threaded portion.

5 9. The storage system (1) as claimed in any one of claims 1 to 8, characterized in that the reservoir (6) comprises at least two metal tubes (A) screwed together, so as to form a column (C) of tubes.

10. An underground storage method for storing fluids using a storage system (1) as claimed in any one of claims 1 to 9, characterized in that it includes at least the following steps:

- 10 - making a hole (2) in a plot of land (3), said hole (2) having a bottom (7),
- providing a support element (5) comprising at least one opening able to receive a joining element (19),
- providing a ventilation device (4) comprising at least one ventilation cavity (9),
- 15 - providing at least one reservoir (6), said reservoir (6) having a longitudinal axis, a lower end (14) and an upper end (16),
- providing a first closure means (15) able to close said reservoir (6) at its lower end (14), and a second closure means (17) able to close the reservoir (6) at its upper end (16),
- 20 - joining said upper end (16) to the support element (5) via the joining element (19) such that the reservoir (6) is suspended inside the hole (2) and such that an axial clearance (G) able to absorb any axial thermal expansion of said reservoir (6) remains between the first closure means (15) of the reservoir (6) and the bottom (7) of the hole (2).