

Storage installation for liquified gases

The present invention relates to a storage installation for liquified gases, such as LNG, i.e. gases which at temperatures below 0°C boil at atmospheric pressure
5 and which can be liquified by further cooling.

Such gases may be stored in excavated rock cavities and which constitute a so-called ground depot. The alternative to such ground depots is tanks laid into the ground, entirely above the ground level, or tanks partly above and partly below the
10 ground level. If the facility is positioned entirely or partly below ground level, the storage may be above, at or below the ground- water level. The pressure above the liquified gas may be about 1 bar abs., normally slightly higher, such as 1,1 bar abs.. In the liquified gas the pressure, of course, increases downwards from the surface of the liquid but the pressure would be lower than in the possibly
15 surrounding ground-water. The low temperature of the gas can be maintained by feeding the gas (gaseous phase) above the surface of the liquid to a refrigerator to be recondensed to a liquid which is fed back into the tanks, according to conventional techniques.

20 In rock cavities for this kind of storage it has been attempted to use a concrete lining against the rock. The store has been insulated by adhering insulation onto the concrete lining, or in some cases, directly onto the rock without the use of steel lining. Experiments have shown that due to dissimilar contraction during the cooling, adherence problems arise between the different materials, the result of
25 which being a great risk for the insulation to fall down. Also, if it is not sealed off by means of a membrane of special steel, such a storage facility is prone to leakage, resulting in excessive expenses.

Tanks of steel or tanks of concrete lined with steel have been employed as tanks
30 on or below the ground. Due to the lower temperature level highly costly special steel must be used, as steel of a more normal type becomes brittle at low temperatures. The cost for producing such installations is a serious disadvantage.

Through the present invention an installation has been arrived at which solves the above problems and which also is considerably cheaper than prior art facilities for storing liquified gases at temperatures below about -45°C (in tanks of steel).

- 5 The installation according to the present invention for storing gases in a cavity defined by rock or an outer concrete shell comprises a tank for the gas, the tank being made of concrete and possibly thermally insulated, the installation being characterized in that the tank is entirely or partly surrounded by a mass filling a space between the tank and the rock or the concrete shell, the mass itself being
10 thermally insulating and capable of causing sealing.

The sealing is performed by the mass filling the space or void, either by means of the mass as such or by means of one or more membranes which may be placed within the mass, or on the outer or inner face thereof.

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- The invention makes it possible to make such an installation either in an excavated rock cavity, or in loose soil, partly within the loose soil and partly above ground level, or entirely above ground level. Here, the expression loose soil refers to any substance that is not a solid matter, such as earth, sand,
20 shingle, gravel, or a mixture thereof. The loose soil may be arranged around the installation, or a depression may be formed in the loose soil in which the installation is placed. Where an outer shell encapsules the tank, the shell absorbs the pressure from within the mass filling the space such that the installation is independent from the surrounding medium which, as indicated, may be loose soil,
25 partly loose soil and partly atmospheric air, or atmospheric air exclusively.

- When it is to possess sealing capabilities, the mass filling the space may be clay, for example, possibly added a thermally insulating material. An exemplary additive is loose Leca. The addition of such a material may eventually lead to the
30 avoidance of arranging separate thermal insulation on and/or in the tank, or that such insulation may be substantially reduced. When being cooled from 0°C to a certain temperature, clay has the capability of expanding, and hence it will maintain a tight engagement with the rock or the shell, and with the concrete tank. However, to avoid overloading the tank and/or the shell by pressure caused by

the expansion of the clay, a "crushable material" may be arranged as a shim between the clay and the tank, or between the clay and the shell, such that this "crushable material" crumbles at a certain pressure and prevents the transfer of a to high pressure onto the tank and/or shell. If insulation is placed between the mass and concrete this insulation may act as "crushable material".

The mass filling the space may be a natural or a factory-made product. As the mass itself shall be sealing, its permeability should be extremely small such that the mass acts like a membrane sealing off the installation. An exemplary natural product is clay with a large contents of fine particles. Exemplary factory-made products are clay in the form of powder or pellets (bentonite) to which water, finely grounded limestone, slag from industrial processes, flight ashes (e.g. volcanic), silica dust, etc., may be added. Although it is not mandatory, it is an advantage for the mass to be thermally insulating. Insulation may be arranged in layers inside or outside the tank. Although it is not mandatory, it is also advantageous for the mass to be expanding at temperatures below 0°C.

After the starting-up of the installation and when a stable temperature is present (in reality, the temperature falls as long as the installation is in operation), heat may be supplied to the mass. If the mass is clay or a similar material which becomes brittle and tends to break up at lower temperatures, heat may be supplied such that the mass or portions thereof be kept at a temperature across the entire or portions of the thickness being higher than the temperature at which the mass transforms from being plastic to being brittle. Similarly, if the mass contains one or more membranes, heat may be supplied to avoid cooling down of the membrane or membranes to a temperature where it/they becomes/become brittle or is/are likely to break. The supply of heat makes the choice of material for the membrane or membranes less critical. For example, steel of a normal grade, i.e. not an expensive special steel, may be used.

When the storage facility has been put in operation by being filled with liquified gas, slow cooling of the tank, possible insulation, the mass in the space as well as the rock or shell around the cold gas takes place and the zero-isotherm is constantly moved outwards from the storage. In this connection it should be

noted that insulation may be favourable also in respect of the time that elapses for the starting-up. To prepare the installation for storage liquified gas is supplied, which due to the heat supply from the surroundings (the concrete tank, the possible insulation, the surrounding mass and rock or shell) will evaporate.

- 5 Evaporated gas is removed, and condensed gas that is supplied evaporates such that the temperature of the surroundings constantly becomes lower. The time it takes to bring the surroundings down to such a temperature where the evaporation is minimal and the installation may be regarded as being in stable operation is substantially shortened by thermal insulation in addition to the mass.
- 10 A shortening of the starting-up period is of great economic value due to the very large sums of money invested in such facilities.

- The insulation material also provides the effect that the mass and rock or shell are not subjected to such a low temperature as when insulation is not used. Thus,
- 15 problems regarding sealing of the storage can be avoided.

- The mass between the tank and rock or shell may be of such a kind that it does not contract nor break up at the temperatures occurring in this region. In order to prevent the temperature from being so low that the mass transforms from a
- 20 viscous to a brittle behavior with subsequent cracking, or that the membrane or membranes becomes/become brittle, heating means, such as tubes, hoses, heating elements, combined with temperature sensors, may be mounted, such that heating can be effected to prevent the temperature from being so low that cracking of the mass occurs, or the membrane or membranes becomes/become
- 25 brittle. Such heating means are first put in service when the installation is approaching its approximate stable operation state, as heating during the starting-up would prolong the time for starting-up.

- Such an installation exhibits a high grade of safety. Due to the mass and possible
- 30 ground-water surrounding the tank cracks in the concrete tank, in the possible insulation and/or in the shell will not cause any outward leakage of product or inward ground-water leakage, either by the fact that the mass does not crack, or that the membrane or membranes performs/perform a sealing function.

Compared with the use of steel tanks it is, in addition to the economic savings, achieved the certainty that cracks which may arise in the concrete tank do not have any consequences regarding leakage of the product in liquid or gaseous form, since the surrounding mass, or the mass combined with one or more
5 membranes, and possibly the ground-water, will seal against further outbound leakage.

The thermal insulation of the concrete tank may be external and/or internal. In any case, an insulation material must be used which the product does not
10 penetrate into and which does not react with the product, since cracks in the concrete tank will occur.

In the following an installation according to the invention will be described by way of examples schematically illustrated on the enclosed drawings, on which Figs. 1
15 to 5 show an installation having a tank located in a cavity excavated in rock, while Figs. 6 to 9 show an outer shell around a tank.

Fig. 1 shows a horizontal section through an embodiment of an installation according to the invention.

20 Fig. 2 shows a vertical section through an installation according to the invention.

Fig. 3 shows a vertical section through a somewhat different embodiment of an installation according to the invention.

Fig. 4 shows a horizontal section through an installation according to the invention, with one membrane located in the mass surrounding the
25 concrete tank.

Fig. 5 shows a vertical section through the installation of Fig. 4.

Fig. 6 shows a horizontal section through another embodiment of an installation according to the invention.

Fig. 7 shows a vertical section through the installation of Fig. 6.

30 Fig. 8 shows a horizontal section through an installation according to the invention, with a membrane located in the mass surrounding the concrete tank.

Fig. 9 shows a vertical section through the installation of Fig. 8.

Figure 1 may be regarded as a section through each of the insulated tanks shown in Figs. 2 and 3.

Fig. 1 shows a concrete tank 2 having a circular cross-section. A layer of thermal insulation 3 is arranged outside the tank 2, and the unit comprising a tank 2 and the insulation is surrounded by a mass 5 which also bears against the surrounding rock 6. In its inner chamber 1 the tank 2 contains liquified gas. Between the insulation 3 and mass 5 "crushable material" 4 is inserted, this material being intended to crack if the outer pressure against the tank 2 exceeds a certain value, thus preventing the tank 2 to be overloaded because of swelling of the mass 5 when cooled. Apparently the rock wall generally will not be of a regular shape, such as that shown, but rather be irregular.

Figs. 2 and 3 show vertical cross-sections through two alternative embodiments which have in common that the cylindrical portion of the tank 2, the insulation 3, the "crushable material" 4 and the mass 5 may be disposed as shown in figure 1. Also, the roof 7 is similarly constructed as the cylindrical portion, except that the roof 7 is shown as being dome-shaped. "Crushable elements" 4 are inserted in the roof 7, too. Contrary to the embodiment of Fig. 2, the embodiment of Fig. 3 comprises crushable material underneath the concrete tank.

The embodiment of Fig. 2 comprises a concrete sole 8 having branches 9 (ribs, posts) down to the rock, and in between these branches there are voids containing insulation and mass, correspondingly as the wall and roof of the tank. The sole 8 and branches 9 support the rest of the tank 2.

The embodiment of Fig. 3 comprises, on the other hand, a bottom 10 constructed with insulation as the rest of the tank, while a mass 5 corresponding to that surrounding the tank and covering the roof 7 forms the foundation for the tank. Thus, the tank 2 and the insulation 3 are completely surrounded by the mass 5 which also supports the tank. The bottom of the tank 2 and the insulation 3 beneath the bottom are dome-shaped, correspondingly as the roof 7. It is well known that dome-shaped end portions are far more capable of withstanding loading from outside than planar end portions, for example.

The embodiment of Figs. 4 and 5 is similar to the embodiment of Figs. 1 and 3 by comprising the same elements but differ therefrom by the fact that the mass 5 contains a sealing membrane 11. It should be understood that the membrane may be located inside or outside the mass and that one or more membranes 11
5 may be employed. In this case, the mass 5 may be a liquid permeable material, such as sand.

Fig. 6 illustrates a concrete tank 2 having a circular cross-section. A layer of thermal insulation 3 is arranged outside the tank 2, and the unit comprising the
10 tank 2 and the insulation is surrounded by a mass 5 which also bears against a surrounding shell 10 made of concrete. In its inner chamber 1 the tank 2 contains liquified gas. A "crushable material" 4 is inserted between the insulation 3 and mass 5, being intended to crack if the outer pressure against the tank 2 exceeds a certain value, thus preventing overloading of the tank 2 and/or shell 10 due to
15 the swelling of the mass 5 when cooled. The Fig. illustrates an installation surrounded by loose soil 8. The loose soil may be arranged around the installation, or a depression may be excavated in loose soil in which the installation is entirely or partly disposed.

20 Fig. 7 is a vertical cross-sectional view through the installation shown in Fig. 6. Besides the elements that appear from Fig. 6, Fig. 7 shows a dome-shaped bottom 6 and a dome-shaped top 7 of the tank 2, a roof covering 12 made of metal or some other weather proof material, a shell bottom 9 and an upper shell collar 11. It is well known that dome-shaped end portions are far more capable of
25 withstanding loading from outside than planar end portions, for example.

Thus, the installation is located in a depression in the loose soil 8, or the loose soil 8 is arranged around the installation, such that only the top 7 and the roof covering 12 extend above the loose soil 8.

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Even underneath the bottom 6 "crushable elements" 4 are inserted.

The embodiment of Figs. 8 and 9 is similar to the embodiment of Figs. 6 and 7 by comprising the same elements, but differ therefrom by the fact that the mass 5

contains a sealing membrane 13. It should be understood that the membrane may be located outside or inside the mass 5 and that one or more membranes 13 may be employed. In this case, the mass 5 may be a liquid permeable material, such as sand.

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The embodiments shown should be regarded as being schematic. A sump or recession for a loading pump and tubings is not shown, nor is a possible heating means illustrated.

- 10 Several modifications are possible relatively to the examples shown. For example, insulation may also be mounted internally in the tank 2. It is also envisaged to add to the mass 5 sufficient insulating material, such as Leca, such that the insulation on or in the tank 2 can be omitted, except that the top 7 should be insulated if it is not covered by the mass 5.

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**CLAIMS**

1. Installation for storing liquified gas in a cavity defined by rock or an outer concrete shell (10), comprising a tank (2) for the gas, the tank (2) being made of concrete and possibly being thermally insulated,
5 characterized in that the tank (2) is entirely or partly surrounded by a mass (5) filling a void between the tank (2) and the rock or the outer shell (10), the mass itself being capable of causing sealing and is thermally insulating.
- 10 2. An installation according to claim 1, characterized in that the mass (5) is natural clay.
3. An installation according to claim 1, characterized in that the mass (5) is clay made of powder or pellets to which water is added.
- 15 4. An installation according to claim 1, characterized in that the mass (5) is a factory-made material, such a finely grounded limestone or slag.
5. An installation according to claim 1, characterized in that the
20 mass (5) is a granulate material, at least one sealing membrane (13) being included in the mass (5), or surrounding the mass on its outside and/or inside.
6. An installation according to claim 1, characterized in that the mass (5) is sand.
- 25 7. An installation according to anyone of the claims 1 to 6, characterized in that the mass (5) contains an additive of a thermally insulating material.
- 30 8. An installation according to claim 1, characterized in that the installation is located entirely or partly in loose soil (8) which entirely or partly surrounds the shell (10).

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9. An installation according to claim 1, characterized in that the installation is located above ground level.

10. An installation according to anyone of claims 1 to 9,
5 characterized in that the mass (5) contains one or more membranes.

11. An installation according to anyone of claims 1 to 10,
characterized in that the mass (5) is surrounded by one or more
membranes.

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