

DEVICE AND METHOD FOR COOLING A LIQUEFIED GAS

Technical field

The invention relates to the field of the cooling of gaseous bodies stored in a liquefied form, and relates notably to the cooling of a fuel gas such as liquefied
5 natural gas (LNG).

Technological background

The liquefied natural gas is stored in tight and thermally insulating tanks at cryogenic temperatures. Such tanks can form part of an onshore storage installation or be installed in a floating structure, such as a methane tanker for example.

10 The thermal insulation barriers of the liquefied natural gas storage tanks are inevitably the seat of a thermal flux tending to reheat the contents of the tank. This reheating is reflected in an increase in the enthalpy of the contents of the tank and, consequently, in a distancing of all or part of the cargo from its conditions of equilibrium at quasi-atmospheric pressure. This increase in enthalpy is therefore
15 likely to bring about an evaporation of the liquefied natural gas and a loss of natural gas stored in liquid form.

In order to limit the increase in enthalpy of the liquefied natural gas, the thermal insulation of the tanks is regularly improved. However, although the thermal insulation capacities of the tanks tend to increase, the rate of reheating of the
20 liquefied natural gas remains substantial.

Moreover, in order to limit the evaporation of the liquefied natural gas, it is also known practice to store the liquefied natural gas in tanks under pressure so as to obtain a shift on the curve of liquid-vapor equilibrium of the liquefied gas considered, thus increasing its vaporization temperature. The liquefied natural gas
25 can thus be stored at higher temperatures which has the effect of limiting the evaporation of the natural gas. However, such storage under pressure necessitates a mechanical strength which is not offered by all the types of tank and in particular by the tanks of prismatic geometry with which the liquefied natural gas tankers are mostly equipped.

It is indeed known practice in the prior art to use the gas derived from the natural evaporation to supply a unit using natural gas as fuel. Thus, on a methane tanker for example, the evaporated gas is used to supply the power train used to propel the ship or generator sets supplying the electricity necessary to the operation of the onboard equipment. However, while such a method makes it possible to vaporize the evaporated gas in the tank, it does not make it possible to significantly reduce the natural evaporation.

Summary

An idea on which the invention is based is to propose a device for cooling a liquefied gas that makes it possible to limit the natural evaporation of the liquefied gas while keeping it in a thermodynamic state allowing it to be stored sustainably.

According to one embodiment, the invention provides a vaporization device for cooling a liquefied gas; said vaporization device comprising:

- a vaporization chamber arranged in the interior space of a container intended to be filled with liquefied gas, the vaporization chamber comprising heat exchange walls allowing an exchange of heat between an interior space of the vaporization chamber and a liquefied gas present in the interior space of the container;
- an inlet circuit comprising an intake emerging in the interior space of the container for withdrawing a flow of liquefied gas in liquid phase from the container and a head loss member emerging in the interior space of the vaporization chamber in order to expand the withdrawn gas flow;
- an outlet circuit arranged to evacuate the withdrawn gas flow, in gaseous phase from the vaporization chamber to a vapor phase gas usage circuit; said outlet circuit comprising a vacuum pump capable of sucking the gas flow into the vaporization chamber, of discharging it to the vapor phase gas usage circuit and of maintaining an absolute pressure lower than atmospheric pressure in the vaporization chamber.

Thus, such a device makes it possible to fully exploit the vaporization of the gas intended to supply equipment consuming gas in vapor phase to cool the liquefied gas stored in the tank by subtracting from the latter the latent vaporization heat.

Furthermore, by virtue of such a device, the vaporization of the liquefied gas intended to supply the equipment consuming gas in vapor phase can be produced without using an external heat source, unlike the forced vaporization

installations using an exchange of heat with sea water, an intermediate liquid or combustion gases derived from the motorization or from specific burners. The liquefied gas present in the interior space of the container then acts as hot source for the fraction intended for the equipment consuming gas in vapor phase. However, 5 in some embodiments, such an external heat source can also be provided additionally.

Furthermore, by maintaining the gas flow circulating in the vaporization chamber at an absolute pressure lower than atmospheric pressure, the liquefied gas, stored in the tank, can be cooled to a temperature lower than its vaporization 10 equilibrium temperature at atmospheric pressure. Consequently, the liquefied gas can be maintained in a sub-cooled thermodynamic state allowing it to be stored or transferred in a tank at atmospheric or quasi-atmospheric pressure while maintaining a low, even zero, rate of evaporation of the liquefied gas.

Such a device also offers the advantage of limiting the variations of 15 composition of the liquefied gas stored in the tank and of the gas in vapor phase conducted to a usage circuit. In effect, when the liquefied gas is a gaseous mixture made up of a plurality of components, the vapor phase derived from the natural evaporation naturally exhibits a composition richer in the most volatile components than the liquid phase, notably nitrogen. Furthermore, the composition of the vapor 20 phase tends to vary over time. Thus, these variations of composition cause the calorific value of the gas derived from the natural evaporation like that of the liquefied gas remaining in the tank to be variable over time when the natural evaporation prevails. Now, supplying equipment with a fuel gas whose heat capacity undergoes significant variations of calorific value is likely to result in an imperfect 25 combustion of the gas, equipment operating faults and variable equipment efficiency. Consequently, by extracting in liquefied form the gas intended to supply gas-consuming equipment, the variations of composition of the gas are limited.

According to other advantageous embodiments, such a device can have one or more of the following features:

- 30 - the vacuum pump is capable of placing the gas flow circulating in the vaporization chamber under an absolute pressure of between 120 and 950 mbar, preferably between 500 and 950 mbar.
- the inlet circuit comprises a pressure regulator upstream of the head loss member.

- the inlet circuit comprises, upstream of the head loss member, an additional pump capable of sucking the flow of liquefied gas in liquid phase and of generating a discharge pressure higher than the maximum hydrostatic pressure likely to be reached in the interior space of the container at the intake of the inlet circuit.
- 5 - the inlet circuit further comprises a pressure regulator arranged downstream of the additional pump capable of limiting the pressure of the liquefied gas discharged by the additional pump in the inlet duct to a threshold pressure lower than the discharge pressure of the additional pump.
- according to an embodiment, the inlet circuit comprises a plurality of head loss
- 10 members formed from spray nozzles capable of spraying the liquefied gas inside the vaporization chamber. Advantageously, the spray nozzles spray the liquefied gas finely and uniformly against the interior wall of the vaporization chamber.
- the inlet circuit can comprise one or more head loss members.
- according to an embodiment, the or each head loss member is chosen from a
- 15 variation of the flow section of the inlet circuit, such as an orifice formed in a transverse wall arranged between the inlet duct and the vaporization chamber, and having a diameter less than that of the inlet duct, a porous material, or an isentropic expansion machine.
- the heat exchange walls comprise fins, intended to augment the exchange surface
- 20 of the vaporization chamber.
- the device comprises a device for recovering and evacuating a heavy fraction of the withdrawn liquefied gas, associated with the vaporization chamber.
- the vaporization chamber has a slope and the device for recovering and evacuating a heavy fraction of the liquefied gas comprises a receptacle linked to a
- 25 low point of the vaporization chamber so as to collect the heavy fraction by gravity.
- the receptacle is coupled to the vaporization chamber by a valve, a non-return valve, a duct or a trap.
- the device for recovering and evacuating a heavy fraction of the liquefied gas further comprises an evacuation duct linked to the receptacle.
- 30 - the evacuation duct is equipped with a pump for discharging the heavy fraction in liquid phase through the evacuation duct.

- the device for recovering and evacuating a heavy fraction of the liquefied gas further comprises a heating device capable of heating an interior space of the receptacle to vaporize the heavy fraction; the evacuation duct being capable of evacuating the heavy fraction in vapor phase.
- 5 - the evacuation duct is linked to the receptacle via a valve or a non-return valve.
- the interior space of the receptacle is connected with the outlet circuit of the device and the outlet circuit is coupled to a fluid supply device via a Y-coupling in order to be able to discharge fluid through the outlet circuit to the receptacle so as to discharge the heavy fraction contained in the receptacle to the evacuation duct.
- 10 - the evacuation duct is linked to the vapor phase gas usage circuit.
- the evacuation duct extends from the receptacle to the container or to a heavy fraction conditioning device.
 - according to an embodiment, the device further comprises an additional heat exchanger which is coupled upstream to the vaporization chamber and downstream
- 15 to the outlet circuit, said additional exchanger being arranged in an upper portion of the interior space of the container intended to be filled with liquefied gas. Such an additional heat exchanger is particularly advantageous in that it allows a re-condensation of the gaseous phase derived from the natural evaporation inside the container and thus makes it possible to limit the overpressures inside said container.
- 20 - the additional heat exchanger is arranged, at least partially above a maximum level of filling of the container, so as to allow an exchange of heat between the withdrawn gas flow and a gaseous phase of the liquefied gas stored in the container. In other words, the additional heat exchanger is at least partially in contact with the gaseous phase of the liquefied gas stored in the container.
- 25 - according to an embodiment, the device further comprises a first bypass line, a first three-way coupling coupling the vaporization chamber to the additional heat exchanger and to the bypass line and a valve capable of selectively allowing or preventing the passage of the gas flow withdrawn from the vaporization chamber to the first bypass line. According to an embodiment, the valve is a three-way valve
- 30 capable of selectively coupling the vaporization chamber to the additional heat exchanger or to the first bypass line. In other words, the three-way valve is capable of selectively assuming a first position in which the withdrawn gas flow is conducted

from the vaporization chamber to the additional heat exchanger and a second position in which the withdrawn gas flow is conducted from the vaporization chamber to the first bypass duct in order to short-circuit the additional heat exchanger. According to another embodiment, the valve is a two-way valve with
5 which the first bypass line is equipped.

- according to an embodiment, the device comprises a second three-way coupling capable of coupling the additional heat exchanger to the outlet circuit and the bypass line to the outlet circuit. According to a variant, the second three-way coupling is a switchable coupling capable of selectively coupling the additional heat
10 exchanger or the first bypass line to the outlet circuit. According to another embodiment, the second three-way coupling does not have switching capability such that its three ways are coupled permanently.

- according to an embodiment, the vaporization chamber and the additional heat exchanger are arranged continuously one after the other, that is to say without
15 interruption. In other words, the exchange surfaces of the additional exchanger extend in the extension of the exchange surfaces of the vaporization chamber.

- the device further comprises a second bypass line which is, on the one hand, coupled to the inlet circuit, upstream of the head loss member, and, on the other hand, coupled to the additional heat exchanger, in order to conduct at least a part of
20 the withdrawn liquefied gas flow from the inlet circuit to the bypass line, the device further comprising regulation means capable of regulating the flow rates of gas flows circulating respectively through the vaporization chamber and through said second bypass line. At least a part of the withdrawn liquefied gas flow thus passes through the second bypass line without passing through the vaporization chamber, the
25 vaporization of said part of the withdrawn gas flow then taking place in the additional heat exchanger. The regulation means are capable of regulating the gas flow rates circulating respectively through the vaporization chamber and through said second bypass line as a function of a variable representative of the pressure of the gaseous phase in the interior space of the container.

30 According to an embodiment, the invention also provides a liquefied gas storage and cooling installation comprising a container having an interior space and an above-mentioned vaporization device, the vaporization chamber of said vaporization device being arranged in the interior space of said container.

According to other advantageous embodiments, such an installation can have one or more of the following features:

- the container is a tight and thermally insulating tank.
- the container is a tight and thermally insulating ancillary tank, the installation
5 further comprising a tight and thermally insulating main tank, a delivery duct and a return duct linking the main tank and the ancillary tank and a pump capable of circulating liquefied gas between the main tank and the ancillary tank through the delivery duct and the return duct.
- the container is filled with liquefied fuel gas chosen from liquefied natural gas,
10 ethane and liquefied petroleum gas.
- in an embodiment, the tight and thermally insulating tank is a membrane tank. In other embodiments, the tank is a type B or C type structural tank.

According to an embodiment, the invention also provides a method for cooling a liquefied gas contained in the interior space of a container, the cooling
15 method comprising:

- withdrawing a flow of liquefied gas in the container containing a quantity of liquefied gas having to be cooled and conducting it to a vaporization chamber arranged in the interior space of the container;
- generating an absolute pressure lower than atmospheric pressure inside the
20 vaporization chamber;
- effecting a heat exchange through the walls of the vaporization chamber between the flow of gas withdrawn and expanded in the vaporization chamber and the liquefied gas contained in the container so as to vaporize the withdrawn liquefied gas flow by absorbing calories from the liquefied gas contained in the container; and
25
- conducting the withdrawn gas flow in vapor phase to a vapor phase gas usage circuit.

According to an embodiment, an absolute pressure lying between 120 and 950 mbar, preferably lying between 650 and 850 mbar, is maintained inside the
30 vaporization chamber.

According to an embodiment, the liquefied gas is stored in the interior space of the container in a state of two-phase equilibrium and has a lower liquid

phase and an upper gaseous phase and the gas flow withdrawn from the vaporization chamber is conducted to an additional exchanger in contact at least partially, even fully, with the upper gaseous phase in order to effect a heat exchange between the withdrawn gas flow and the upper gaseous phase before conducting
5 the withdrawn gas flow to the vapor phase gas usage circuit.

Advantageously, the vaporization chamber is coupled to the additional heat exchanger and to a bypass line making it possible to circumvent the additional heat exchanger via a first three-way coupling, a valve being capable of selectively allowing or preventing the passage of the withdrawn gas flow to the bypass line and
10 said valve is controlled in order to allow or prevent the passage of the withdrawn gas flow to the bypass line as a function of a variable representative of the pressure of the upper gaseous phase.

According to an embodiment, the valve is a switchable three-way valve and said three-way valve is switched in order to conduct the withdrawn gas flow from the
15 vaporization chamber to the additional heat exchanger or to the bypass line as a function of the variable representative of the pressure of the upper gaseous phase.

According to a variant embodiment, the pressure of the gaseous phase is measured inside the container and the valve is controlled as a function of a pressure threshold and of the measured pressure of the gaseous phase. More particularly,
20 the withdrawn gas flow is conducted from the vaporization chamber to the additional heat exchanger when the measured pressure of the gaseous phase is above said pressure threshold. Similarly, the withdrawn gas flow is conducted from the vaporization chamber to the bypass line in order to short-circuit the additional heat exchanger when the measured pressure of the gaseous phase is below a pressure
25 threshold.

According to an embodiment, a flow of liquefied gas is withdrawn from the container and it is conducted to an additional heat exchanger at least partially in contact with the upper gaseous phase in order to effect an exchange of heat between said withdrawn gas flow and the upper gaseous phase. This mode of
30 operation makes it possible to increase the heat exchange implemented at the level of the additional heat exchanger and is consequently implemented when the pressure of the gaseous phase exceeds a threshold.

According to an embodiment, the invention relates to a ship comprising an above-mentioned installation for the storage and the cooling of a liquefied gas.

According to an embodiment, the vapor phase gas usage circuit is an energy production unit, such as a unit for propelling the ship.

5 According to an embodiment, the invention also provides a method for loading or offloading such a ship, in which a fluid is routed through insulated lines from or to a floating or onshore storage installation to or from the tank of the ship.

Certain aspects of the invention start from the observation that the storage of the liquefied natural gas under pressure in reality leads to a shifting of the point of
10 two-phase equilibrium of the gas on the liquid-vapor equilibrium curve. Thus, when the liquefied natural gas, which was thus stored under pressure, is transferred to an installation in which the liquefied natural gas is stored at a lower pressure, such as atmospheric pressure, the transfer is accompanied by a strong vaporization of the liquefied natural gas, unless the natural gas has been subjected to a prior cooling
15 treatment which is complex and costly.

Brief description of the figures

The invention will be better understood, and other aims, details, features and advantages thereof will become more clearly apparent from the following description of several particular embodiments of the invention, given purely in an
20 illustrative and nonlimiting manner, with reference to the attached drawings

- **Figure 1** schematically illustrates a liquefied gas storage and cooling installation according to a first embodiment.
- **Figure 2** schematically illustrates a liquefied gas storage and cooling installation according to a second embodiment.
- 25 - **Figure 3** is a diagram of liquid-vapor equilibrium of methane.
- **Figure 4** schematically illustrates a vaporization device according to an embodiment.
- **Figure 5** is a perspective view of the vaporization device of figure 4, partially cut.
- 30 - **Figure 6** is a perspective view of a vaporization device according to another embodiment.

- **Figure 7** is a perspective view of a membrane tank and of a vaporization device submerged in the tank.
- **Figure 8** schematically illustrates a vaporization device equipped with a device for recovering and evacuating the heavy fraction of the liquefied gas according to a first embodiment.
- **Figure 9** schematically illustrates a vaporization device equipped with a device for recovering and evacuating the heavy fraction of the liquefied gas according to a second embodiment.
- **Figure 10** schematically illustrates a vaporization device equipped with a device for recovering and evacuating the heavy fraction of the liquefied gas according to a third embodiment.
- **Figure 11** is a sectional schematic representation of a methane tanker and a loading/offloading terminal for this tank.
- **Figure 12** is another schematic representation of the liquefied gas storage and cooling installation.
- **Figure 13** illustrates a liquefied gas storage and cooling installation according to a third embodiment.
- **Figure 14** illustrates a liquefied gas storage and cooling installation according to a fourth embodiment.
- **Figure 15** illustrates a liquefied gas storage and cooling installation according to a fifth embodiment.
- **Figure 16** illustrates a liquefied gas storage and cooling installation according to a sixth embodiment.
- **Figure 17** illustrates a liquefied gas storage and cooling installation according to a seventh embodiment.

Detailed description of embodiments

In the description and the claims, the term "gas" has a generic nature and targets without preference a gas consisting of a single pure body or a gaseous mixture consisting of a plurality of components. A liquefied gas thus describes a chemical body or a mixture of chemical bodies which has been placed in a liquid

phase at low temperature and which would appear in a vapor phase in normal conditions of temperature and pressure.

In figure 1, a liquefied gas storage and cooling installation 1 according to a first embodiment is represented. Such an installation 1 can be installed onshore or
5 on a floating structure. In the case of an onshore structure, the installation can be intended for a storage of liquefied natural gas having units consuming gas in vapor form. These consuming units can be generator sets, vapor generators, burners or any other unit consuming gas in vapor form whether it is neighboring the storage or on the vapor gas distribution network supplied by said storage.

10 In the case of a floating structure, the installation can be intended for a liquefied natural gas tanker, such as a methane tanker, but can also be intended for any ship in which the power train, the generator sets, the vapor generators or any other consuming unit are supplied with gas. As an example, it can thus be a merchandise transport ship, a passenger transport ship, a fishing boat, a floating
15 electricity production unit or the like.

The installation 1 comprises a container having an interior space inside which liquefied gas 3 is stored. Here, the container is a tight and thermally insulating tank 2.

According to an embodiment, the tank 2 is a membrane tank making it
20 possible to store liquefied gas, at atmospheric or quasi-atmospheric pressure, the pressure inside such a tank being likely to vary by at most 300 mbar relative to atmospheric pressure.

Such a membrane tank can notably comprise a multilayer structure comprising, from the outside to the inside of the tank 2, a secondary thermally
25 insulating barrier comprising insulating elements resting against a supporting structure, a secondary sealing membrane, a primary thermally insulating barrier comprising insulating elements resting against the secondary sealing membrane and a primary sealing membrane intended to be in contact with the liquefied gas contained in the tank. By way of example, such membrane tanks are notably
30 described in the patent applications WO14057221, FR2691520 and FR2877638.

According to another alternative embodiment, the tank 1 is a type B or C tank. Such a tank is self-standing and can notably have a parallelepipedal, prismatic, spherical, cylindrical or multilobe form. The type C tanks have the

particular feature of allowing a storage of liquefied natural gas at pressures substantially higher than atmospheric pressure.

The liquefied gas 3 is a fuel gas. The liquefied gas 3 can notably be a liquefied natural gas (LNG), that is to say a gaseous mixture mostly comprising methane and one or more other hydrocarbons, such as ethane, propane, n-butane, i-butane, n-pentane, i-pentane, neopentane, and nitrogen in small proportion. The liquefied natural gas is stored at atmospheric pressure at a temperature of approximately -162°C .

The fuel gas can also be ethane or a liquefied petroleum gas (LPG), that is to say a mixture of hydrocarbons derived from the refining of oil essentially comprising propane and butane.

The installation 1 comprises a vaporization device 4 intended to withdraw a flow of gas in liquid phase from the container and expand it in order to vaporize it by using the latent vaporization heat of the gas to cool the liquefied gas 3 remaining in the container.

the principle of operation of such a vaporization device 4 is recalled in relation to figure 3 which represents a diagram of liquid-vapor equilibrium of methane. This diagram represents the domain, denoted L, in which the methane appears in liquid phase and the domain, denoted V, in which the methane appears in vapor phase, as a function of the pressure represented on the X axis and of the temperature on the Y axis.

The point P1 represents a state of two-phase equilibrium corresponding to the state of the methane stored in a tank 2 at atmospheric pressure and at a temperature of approximately -162°C . When methane in such a state of equilibrium is withdrawn from the tank 2 then expanded in the vaporization device 4, for example at an absolute pressure of approximately 500 mbar, the equilibrium of the expanded methane shifts to the left up to the point P2. The duly expanded methane thus undergoes a temperature reduction of approximately 7°C . Consequently, the withdrawn methane being placed in thermal contact via the vaporization device 4 with the methane remaining in the tank 2, it is at least partially vaporized and, by being vaporized, subtracts from the liquid methane stored in the tank 2 the calories necessary to its vaporization which makes it possible to cool the liquid methane remaining in the tank 2.

Returning to figure 1, it is observed that the vaporization device 4 comprises:

- an inlet circuit 5 comprising an intake submerged in the liquefied gas 3 stored in the tank 2 ;
- 5 - one or more vaporization chambers 14 submerged in the liquefied gas 3 stored in the tank 2 and comprising heat exchange walls 6, submerged in the liquefied gas 3 stored in the tank 2, so as to place the withdrawn gas flow in thermal contact with the liquefied gas 3 remaining in the tank 2; and
- an outlet circuit 7 for evacuating the flow of gas in vapor phase to a vapor phase
- 10 gas usage circuit 8.

The inlet circuit 5 is equipped with one or more head loss members, not illustrated in figure 1, making it possible to create a head loss and emerging inside the vaporization chamber 14 so as to expand the withdrawn liquefied gas flow.

The vaporization device 4 is also equipped with a vacuum pump 9, arranged outside of the tank and associated with the outlet circuit 7. The vacuum pump 9 makes it possible to suck a flow of liquefied gas stored in the tank 2 to the vaporization chamber 14 and to discharge it in vapor phase to a vapor phase gas usage circuit 8.

The vacuum pump 9 is further dimensioned so as to keep the vaporization chamber 14 under an absolute pressure lower than atmospheric pressure.

For the liquefied natural gas, the absolute working pressure prevailing inside the vaporization chamber 14 lies between 120 and 950 mbar, advantageously between 500 and 950 mbar, more particularly between 650 and 850 mbar, and preferably of the order of 750 mbar.

It is in fact essential for the working pressure inside the vaporization chamber 14 to be greater than the pressure corresponding to the triple point of the methane phase diagram so as to avoid a solidification of the natural gas inside the vaporization chamber 14. Moreover, an increase in the working pressure has the effect of reducing the temperature difference between the temperature of the gas inside the vaporization chamber 14 and the temperature of the liquefied gas remaining in the tank 2. In this case, the exchange surface of the vaporization chamber 14 needed to obtain a same refrigerating capacity must be increased. On the other hand, a reduction of the working pressure has the effect of increasing the

above-mentioned temperature difference and thus consequently reduces the exchange surface needed to obtain a same refrigerating capacity. However, the reduction of the working pressure has the drawback of reducing the heat exchange efficiency. Consequently, the above-mentioned working pressure ranges make it possible to offer a good compromise between the compactness of the vaporization device 4 and its performance levels.

The vacuum pump 9 can be dimensioned according to the vapor phase gas demand of the vapor phase gas usage circuit 8. In an embodiment, the vacuum pump 9 is capable of transferring a sufficient vapor flow rate to ensure all the supply of gas in vapor phase needed to supply the vapor phase gas usage circuit 8. The vacuum pump 9 must therefore have a flow rate/pressure characteristic suited to the need of the vapor phase gas usage circuit 8. As an example, the centrifugal fan marketed by the company VentMeca® under the reference Ventmeca 126 may prove appropriate for certain applications. Such a centrifugal fan makes it possible to ensure a flow rate of $3.3 \text{ m}^3/\text{s}$ by generating a 250 mbar vacuum.

The vacuum pump 9 is a cryogenic pump, that is to say capable of supporting cryogenic temperatures lower than -150°C . It must also conform to the ATEX regulation, that is to say designed to eliminate any risk of explosion.

In the embodiment of figure 1, a single vacuum pump 9 makes it possible to ensure the circulation of the gas flow through the vaporization chamber 14 in order to ensure a cooling of the liquefied gas 3 stored in the tank 2 and a supply of gas in vapor phase for an energy production unit. It can also be seen in figure 1 that only the outlet circuit 7 passes through the structure of the tank 2, which limits the thermal losses, reduces the risks of sealing loss and simplifies the design of the structure with all the tight and insulating barriers.

In the case of an installation 1 on board a ship, the vapor phase gas usage circuit 8 can notably be linked to an energy production unit of the power train, not represented, used to propel the ship. Such an energy production unit is notably chosen from heat engines, fuel cells and gas turbines. When the energy production unit is a heat engine, the engine can have a mixed diesel-natural gas supply. Such engines can operate, either in diesel mode in which the engine is fully powered by diesel or in natural gas mode in which the fuel of the engine mainly consists of

natural gas although a small quantity of pilot diesel is injected to initiate the combustion.

Moreover, according to an embodiment, the evaporated gas usage circuit 8 further comprises a supplementary heat exchanger, not illustrated, making it possible to further heat the gas flow in vapor phase to temperatures compatible with the operation of the gas-consuming unit. The supplementary heat exchanger can notably ensure a thermal contact between the gas flow in vapor phase and sea water or fuel gases generated by an energy production unit.

According to an embodiment, the vapor phase gas usage circuit 8 can also comprise a compressor making it possible to heat up the gas flow in vapor phase and to compress it at pressures compatible with the specifications of the energy production units supplied with fuel gas, for example of the order of 5 to 6 bar absolute for some energy production units.

The inlet circuit 5 is equipped with a valve 32 making it possible to cut the supply of liquefied gas at the inlet of the vaporization device 4.

The structure of a vaporization device 4 according to an embodiment is illustrated in figures 4 and 5.

The vaporization device 4 comprises, at the upstream end of the inlet circuit 5, a filter 10, represented in figure 5, making it possible to avoid impurities contained in the tank 2 being introduced into the inlet circuit 5 of the vaporization device 4.

Moreover, the inlet circuit 5 comprises several spray booms 11. As illustrated in figure 4, each spray boom 11 comprises a tube 12 which is equipped with a plurality of spray nozzles 13, also called sprayers and/or atomizers, each having one or more orifices making it possible to spray the gas in liquid phase in the form of fine droplets. Each spray boom 11 extends inside a vaporization chamber 14, of tubular form. Given the variation of flow section generated by each spray nozzle 13, head losses making it possible to expand the withdrawn gas flow are generated. Furthermore, the fragmentation into fine droplets promotes the vaporization by increasing the liquid phase exchange surface.

Note that, in other embodiments that are not represented, the head losses making it possible to expand the withdrawn gas flow are not generated by spray nozzles but:

- by a simple variation of the flow section, such that one or more orifices, for example in the form of capillaries or expansion needles with electronic or thermostatic piloting, formed in a transverse wall arranged between the inlet duct and the vaporization chamber, and each having a diameter much smaller than that of the inlet duct,
- by a porous material, such as ceramic foam, metal foam or open-cell polymer foam, housed in the inlet circuit upstream of the vaporization chamber 14; or
- by an isentropic expansion machine, such as an expansion turbine or a passive expansion wheel.

In the embodiment represented, the vaporization chambers 14 are equipped with fins 15 associated with the heat exchange walls 6 of the vaporization chambers 14 and making it possible to augment their exchange surface with the liquefied gas 3 contained in the tank 2. The fins 15 are arranged on the outside of the vaporization chambers 14 and extend parallel to one another at right angles to the longitudinal direction of the vaporization chambers 14. Together, the vaporization chambers 14 and the fins 15 constitute an exchanger of generally parallelepipedal form, that is particularly compact.

The spray nozzles 13 are evenly distributed along the vaporization chambers 14 such that a maximum surface of the walls 6 of the vaporization chambers 14 can be reached by the liquefied gas droplets.

By virtue of their expansion through the spray nozzles 13, the liquefied gas droplets are vaporized by taking, from the liquid gas 3 stored in the tank 2, via the fins 15 and the wall 6 of the vaporization chambers 14, the latent vaporization heat of the liquefied gas.

Moreover, the vaporization chambers 14 emerge in a gas vapor collection manifold 16 forming a portion of the outlet circuit 7 which is coupled to the vapor phase gas usage circuit 8 via the vacuum pump 9.

As an example, to transmit a refrigerating capacity of the order of 300 KW, which corresponds to the thermal flux on four tanks of a standard methane tanker, with a temperature difference of the order of 3°C between the evaporation temperature of the withdrawn gas flow and the temperature of the liquefied gas stored in the tank, the heat exchange walls 6 of the vaporization chamber(s) 14 need to have an exchange surface of the order of 90 m² per tank. To achieve such

an exchange surface, a fin exchanger as described above comprising a 200 mm tubular vaporization chamber 14, fins of square form with a side of 1 m, spaced apart from one another by 50 mm, will have to have a length of approximately 4.7 m.

Although a vaporization device equipped with a fin exchanger as described
 5 above makes it possible to obtain satisfactory thermal performance levels in a limited footprint, the use of any other heat exchange technology will also be able to be envisaged, such as coil or plate or microchannel exchangers for example.

In the embodiment represented in figure 5, the inlet circuit 5 also comprises, upstream of the spray booms 11, a pressure regulator 17 making it
 10 possible to limit the pressure of the liquefied gas, to a threshold pressure, at the inlet of the vaporization device 4. Such a pressure regulator 17 makes it possible to keep the liquefied gas pressure constant at the intake into the inlet circuit 5 regardless of the hydrostatic pressure exerted by the liquefied gas 3 inside the tank 2 and, consequently, regardless of the level of filling of the tank 2. As an example, the
 15 pressure threshold applied by the pressure regulator 17 is of the order of atmospheric pressure.

In an alternative embodiment, represented in figure 6, the inlet duct 5 comprises, upstream of the spray booms 11, an additional pump 33 capable of generating a discharge pressure greater than the hydrostatic pressure exerted by
 20 the liquefied gas 3 inside the tank 1 at the intake into the inlet circuit 5. The inlet circuit 5 is also equipped with a pressure regulator 17, arranged downstream of the additional pump 33, whose threshold pressure is this time set to a value higher than atmospheric pressure but lower than the discharge pressure of the additional pump 33. Such an arrangement also makes it possible to keep the pressure of the
 25 liquefied gas flow taken into the vaporization device 4 constant regardless of the hydrostatic pressure exerted by the liquefied gas 3 stored in the tank 2. Moreover, this embodiment is also advantageous in that the driving pressure at the spray nozzles 13 is greater than in the preceding embodiment, which makes it possible, on the one hand, to limit the number of spray nozzles 13 needed and, on the other
 30 hand, to ensure a greater flow rate stability. As an example, the additional pump 33 can be controlled so as to discharge liquefied gas at a pressure of the order of 6 to 8 bar, whereas the threshold pressure of the pressure limiter 17 is set to approximately 5 bar. Assuming that the vacuum pump 9 generates a relative vacuum of the order of 0.25 bar in the vaporization chamber 14, that is to say an

absolute pressure of the order of 0.76 bar, the driving pressure at the spray nozzles 13 will therefore be of the order of 5.25 bar.

According to an embodiment, represented in figure 7, the vaporization chamber(s) 14 of the vaporization device 4, that is to say the heat exchanger, is
5 arranged at the bottom of the tank 2 so as to ensure its immersion regardless of the level of filling of the tank 2. Depending on the type of tank 2 targeted, the fixing and the support of the heat exchanger of the vaporization device 4 will be able to be done in different ways.

For the type B or C structural tanks that tolerate direct anchorage on their
10 inner surface, the heat exchanger can be borne on and fixed directly against the bottom wall of the tank 2. In such an embodiment, the outlet circuit 7 is then equipped with compensation means, such as bellows or compensation pigtails, making it possible to compensate the expansions/contractions.

For the tanks 2 whose internal surface is not capable of supporting the heat
15 exchanger of the vaporization device 4, such as membrane tanks, the heat exchanger of the vaporization device 4 can be fixed to and supported by a support foot bearing against the supporting structure of the tank 2 so as to transfer the loads to the supporting structure of the tank 2, through the thermal insulation barriers. As an example, a tight and thermally insulating membrane tank 2 equipped with a
20 support foot is disclosed in the document WO2011/157915.

Alternatively, the heat exchanger of the vaporization device 2 can also be fixed to a loading/offloading mast or tower 18, illustrated in figure 6. Such a loading/offloading mast is suspended from the upper deck of the ship and guided at its bottom end so as to limit the moment being exerted at the point of anchorage of
25 the mast to the deck. Such a loading/offloading mast 18 is for example described in the document FR2785034.

Figure 2 illustrates a liquefied gas storage and cooling installation 1 according to a second embodiment.

In this embodiment, the installation comprises a main tank 20 and an
30 ancillary tank 19 that are tight and thermally insulating. The ancillary tank 19 has a smaller capacity than the main tank 20. The ancillary tank 19 is more particularly intended to house the vaporization chamber 1 of the vaporization device 4 and to provide a chamber for the production of the heat exchange between the flow of gas

withdrawn through the vaporization device 7 and the liquefied gas 3 stored in the main tank 20.

For this, the ancillary tank 19 is linked to the main tank 20 via a delivery duct 21 and a return duct 22. The installation 1 also comprises a pump 23 making it possible to circulate the liquefied gas between the main tank 20 and the ancillary tank 19 through the delivery duct 21 and the return duct 22. The delivery duct 21 emerges in proximity to the bottom of the main tank 20 so as to allow the pumping of the liquefied gas stored in the main tank 20 even when its level of filling is low.

Such an embodiment is advantageous in that it allows a better standardization of the temperature of the liquefied gas and limits the creation of thermal layering inside the main tank 20. Also, since the ancillary tank 19 has smaller dimensions than the main tank 20, this embodiment also makes it possible to ensure that the vaporization chamber of the vaporization device 4 is kept submerged almost until the main tank 20 is empty. Finally, such an ancillary tank 19 also allows variant embodiments in which the ancillary tank 19 would be coupled to several main tanks 20 so as to allow a vaporization device 4 to be pooled.

Generally, the invention is not limited to the installations in which the vaporization device is arranged in the interior space of a tight and thermally insulating tank and targets all the installations in which the vaporization device withdraws a liquefied gas flow from a liquefied gas cargo, on the one hand, and extracts calories from the remaining portion of this same cargo to vaporize the withdrawn flow, on the other hand. Thus, in the description and the claims, the term "container" which targets the object inside which the vaporization chamber 14 of the vaporization device 4 is arranged has a generic nature and targets any object capable of containing or transporting liquefied natural gas, such as a tank or a pipeline, for example.

Figures 8 to 10 schematically illustrate vaporization devices 4 equipped with a device for recovering and evacuating the heavy fraction of the liquefied gas 24 according to three distinct embodiments. Such a heavy fraction recovery and evacuation device 24 targets more particularly the installations 1 intended for the storage of a gaseous mixture, such as liquefied natural gas.

The heavy fraction of the gas consists of the least volatile components of the gas, that is to say, for liquefied natural gas, hydrocarbons having the longest

carbon chain. Given its lower volatility, the heavy fraction of the gas is at least partially likely to remain in liquid phase or to condense inside the vaporization chambers 14 of the vaporization device 4. It is therefore appropriate to equip the vaporization device 4 with a heavy fraction recovery device 24 in order to avoid
5 saturating the vaporization chamber 14 with heavy fraction.

In order to allow this recovery of the heavy fraction in liquid phase, the vaporization chambers 14 have a slope allowing the liquid to flow by gravity and direct it to a receptacle 25 arranged at a low point of the slope. For an application on floating structure, the vaporization chamber will ideally be oriented along the most
10 stable axis thereof. For example, for a ship, along the axis of the ship.

In the embodiment of figure 8, the heavy fraction recovery receptacle 25 is associated with an evacuation duct 26 equipped with a pump 27. The evacuation duct 26 makes it possible to conduct the heavy fraction to a heavy fraction conditioning device, not represented, intended to vaporize and set the temperature
15 of this heavy fraction before its transfer to an energy production unit.

In the embodiment represented in figure 9, the heavy fraction recovery receptacle 25 is equipped with a heating device 28, such as a device with electrical resistor(s) or a heat exchanger ensuring an exchange of heat between the heavy fraction of the gas in liquid phase and sea water or fuel gases generated by an
20 energy production unit. The heating device thus makes it possible to vaporize the heavy fraction stored in the recovery receptacle 25 in order to conduct it to an energy production unit via an evacuation duct 26. The receptacle 25 and the evacuation duct 26 are, in this embodiment, thermally insulated so as to limit the transfer of calories from the vapor phase of the heavy fraction to the liquefied gas 3
25 stored in the tank 2 and thus avoiding the re-condensation of the heavy fraction. Moreover, in such an embodiment, the heavy fraction recovery receptacle 26 is coupled to the vaporization chambers 14 via a trap 29 or a non-return valve making it possible to avoid having the evaporated heavy fraction re-introduced into the vaporization chambers 14 of the vaporization device 4.

30 In the embodiment represented in figure 10, the receptacle 25 is coupled to the outlet circuit 7. The outlet circuit 7 is, in this case, coupled to a fluid supply circuit, not represented, via a Y-coupling. Thus, it is possible to pass a fluid into the outlet circuit 7, so as to discharge the heavy fractions to a heavy fraction evacuation

line 26. In an embodiment, the fluid supply circuit can be coupled to the gaseous top of the tank 2 so as to discharge the heavy fractions by means of gas in vapor phase. The heavy fraction evacuation line 26 is then coupled to a heavy fraction conditioning device. In another embodiment, the fluid supply circuit can be a circuit
 5 supplying gas in liquefied form. The heavy fraction evacuation line 26 can then be coupled to the tank 2. The heavy fraction is then rejected into the tank 2.

Moreover, the receptacle 25 is coupled to the evacuation duct 26 via a valve or a non-return valve 30. Also, the receptacle 25 is coupled to the tubular chambers 14 via a valve or a non-return valve 31.

10 Thus, when evacuating the heavy fraction, the valve or non-return valve 31 is in a closed state whereas the valve or non-return valve 30 is in an open state. The circulation of gas through the evaporation chambers 14 is then interrupted. On the other hand, when the circulation of gas through the evaporation chambers 14 is re-established, the valve or non-return valve 31 is in an open state whereas the valve
 15 or non-return valve 30 is in a closed state. Thus, the valve or non-return valve 31 makes it possible to guarantee that the gas in vapor phase in the vaporization chamber 14 is not conducted to the tank 2 when the heavy fraction is being evacuated and the valve or non-return valve 30 then notably makes it possible to avoid having liquefied gas stored in the tank 2 being pumped to the receptacle 25
 20 when the vacuum pump 9 depressurizes the outlet circuit 7.

A liquefied gas storage and cooling installation 1 as described above makes it possible to significantly reduce the rate of evaporation of the liquefied gas. The efficiency of such a storage and cooling installation 1 depends on the ratio between the evaporated gas supply needs of the vapor phase gas usage circuit 8
 25 and the capacity of the tank 2. Thus, for methane tankers whose natural gas needs are typically of the order of 0.1 to 1.5 kg/s and that have a storage capacity that can be greater than 150 000 m³, the natural evaporation of the liquefied natural gas is not fully eliminated but can all the same be reduced by half so as to achieve daily evaporation rates of between 0.04 and 0.06%. For ships for which the aim of the
 30 installation is only to ensure the propulsion of the ship, the capacity of the tank is more restricted, for example of the order of a few hundreds to a few thousands of m³, while having natural gas needs similar to those of the methane tankers, that is to say of the order of 0.1 to 1.5 kg/s. The efficiency of such an installation makes it possible for ships comprising drive systems having a significant natural gas

consumption and tanks of more restricted capacity to obtain almost zero natural evaporation rates.

Figure 12 schematically shows the installation 1 to illustrate the fact that the vaporization device 4 makes it possible to supply both a refrigerating capacity P to the liquefied gas contained in the tank 2 and a flow rate of gas in vapor phase Q to the usage circuit 8. For the dimensioning of the vaporization device 4 and of its constituent elements, notably the vacuum pump 9 and the vaporization chamber 14, the following considerations can be taken into account:

- the dimensioning depends on the refrigerating capacity desired in the container containing the liquefied gas and/or on the flow rate of gas in vapor phase desired in the usage circuit, in permanent operating conditions.

In some applications, the flow rate of gas in vapor phase desired in the usage circuit 8 may be the primary dimensioning criterion for the vaporization device 4. As an illustration, the average power of the main engine in ocean-going ships is typically of the order of a few MW to several tens of MW. If the flow rate of gas in vapor phase Q from the vaporization device 4 does not make it possible to produce a refrigerating capacity corresponding to all of the need in the storage tank, it is possible to provide an auxiliary cooling device (not represented) to add an auxiliary refrigerating capacity P_{aux} to the liquefied gas contained in the storage tank.

In other applications, the refrigerating capacity needed to keep the gas contained in the container at a temperature lower than its vaporization temperature at atmospheric pressure may be the primary dimensioning criterion for the vaporization device 4, notably if the need for gas in vapor phase of the usage circuit 8 is high and excessively cooling the gas in liquid phase contained in the container and/or overdimensioning the vaporization device 4 is undesirable. Thus, if the refrigerating capacity P from the vaporization device 4 does not make it possible to produce the flow rate of gas in vapor phase corresponding to all of the need in the usage circuit 8, it is possible to provide an auxiliary vaporization device (not represented) to add an auxiliary vapor flow rate Q_{aux} to the usage circuit 8. In a corresponding embodiment, the vaporization device 4 is employed in an LNG regasification terminal to both cool the cargo in liquid phase and to supply a part of the flow of gas in vapor phase having to be produced.

- in the vaporization chamber, it is desirable to vaporize all the light fraction of the flow of liquefied gas withdrawn, that is to say the methane in the case of liquefied natural gas, in order to make optimal use of the vaporization chamber 14.
- the refrigerating capacity P obtained depends on the combination of several parameters: mass flow rate of the vacuum pump 9 and latent vaporization heat of the liquefied gas.
- the heat exchanger must be dimensioned to be able to transfer this refrigerating capacity P to the contents of the container.

The liquefied gas storage and cooling installations represented in figures 13 to 17 differ from that represented in figure 1 in that the vaporization device 4 further comprises an additional heat exchanger 34.

Referring to figure 13, it can be seen that the additional heat exchanger 34 is coupled upstream to the vaporization chamber 14 and downstream to the outlet circuit 7. In other words, the additional heat exchanger 34 is arranged between the outlet of the vaporization chamber 14 and the inlet of the outlet circuit 7 such that the flow of gas is likely to be conducted from the vaporization chamber 14 to the additional heat exchanger 34 then from the additional heat exchanger 34 to the outlet circuit 7.

The additional heat exchanger 34 is intended to be placed in contact with the gaseous phase 35 of the fluid stored in the tank 2 and aims to exchange heat between the withdrawn gas flow and the gaseous phase of the fluid stored in the tank 2. In order to allow an exchange with the gaseous phase 35 of the fluid stored in the tank 2, the additional heat exchanger 35 is arranged in the upper portion of the tank 2 and, more particularly, at least partially, even fully, above the maximum limit of filling of the tank 2. As an example, for methane tanks, this maximum limit of filling corresponds to a filling of the order of 98% of the volume of the internal space of the tank 2.

This additional heat exchanger 34 thus acts as a condenser making it possible to condense and/or cool a part of the gaseous phase 35 derived from the natural evaporation in the tank 2. The additional heat exchanger 34 thus makes it possible to augment the heat exchange between the gas flow withdrawn from the tank 2 and the gas remaining in the tank. In effect, the vaporization chamber 6 is not able to transfer all of the calories likely to be exchanged and, at the outlet thereof,

there is inevitably a differential, of the order of a few tenths of degrees to a few degrees, between the temperature of the vaporized gas flow, at the outlet of the vaporization chamber 6, and that of the liquid phase 3 remaining in the tank 2. In other words, the vaporized gas flow leaves the vaporization chamber 14 at a temperature lower than that of the liquid phase stored in the tank. Thus, the additional heat exchanger 34 makes it possible to exploit these available calories to condense a part of the gaseous phase 35 derived from the natural evaporation in the tank 2.

As an example, considering a differential of 2°C between the temperature of the vaporized gas flow, at the outlet of the vaporization chamber 6, and that of the liquid phase remaining in the tank 2, and a flow rate of 1 kg/s, a refrigerating capacity of 4 kW is available to condense a part of the vapor.

Furthermore, unless the tank 2 is filled to its maximum level of filling, the gaseous phase tends to layer inside the tank such that the temperature of the gaseous phase in the upper portion of the tank is much higher than the equilibrium temperature of the liquid phase of the gas stored in the tank.

As an example, for liquefied natural gas stored at a temperature of the order of -161°C, the temperature of the gaseous phase is likely to reach - 80°C in the upper portion of the tank 2. In this case, considering that the flow rate is 1 kg/s, a much greater refrigerating capacity, of the order of 165 kW is available for cooling and condensing a part of the vapor phase.

The additional heat exchanger 34 can notably have a structure similar to that of the heat exchange walls 6 of the vaporization chamber 14. The additional heat exchanger 34 can notably be a fin exchanger. However, it will also be possible to envisage using any other heat exchange technology, such as coil or plate exchangers for example. The additional heat exchanger 34 can also be fixed to the offloading mast or tower, as described and illustrated in relation to figure 7. According to an embodiment not represented, the vaporization chamber 14 and the additional heat exchanger 34 are formed one after the other in a same heat exchange structure of which a submerged portion ensures an exchange with the liquid phase 3 of the gas stored in the tank 2 whereas an emergent portion ensures an exchange with the gaseous phase 35.

In the embodiment represented in figure 13, the vaporization device 4 further comprises a bypass line 36 allowing a short-circuiting of the additional heat exchanger 34. For this, the vaporization device 4 comprises a first three-way coupling, which is here equipped with a three-way valve 37, which is coupled to the vaporization chamber 14, to the bypass line 36 and to the additional heat exchanger 34. The three-way valve 37 is capable of selectively assuming either a first position in which it conducts the flow of gas from the vaporization chamber 14 to the additional heat exchanger 34, or a second position in which it conducts the flow of gas from the vaporization chamber 14 to the bypass line 36 in order to short-circuit the additional heat exchanger 34.

The device further comprises a second three-way coupling coupling the bypass line 36 to the outlet circuit 7 and the additional heat exchanger 34 to the outlet circuit 7. In figure 13, the second three-way coupling is also equipped with a three-way valve 38.

The three-way valve 37, and optionally the three-way valve 38, can notably be controlled as a function of a variable representative of the pressure of the gaseous phase in the tank in order to maintain a gaseous phase 35 pressure below a pressure threshold. Thus, the generation of the overpressures likely to be produced by the natural evaporation of the liquefied natural gas stored inside the tank and likely to damage the tank 2 is avoided.

For this, according to an embodiment, the device comprises a measurement sensor, not represented, capable of delivering a signal representative of the pressure of the gaseous phase 35 to a control unit of the three-way valve 37.

The control unit compares the measured pressure to a pressure threshold and actuates the three-way valve 37 to its first position in which it conducts the flow of gas from the vaporization chamber 14 to the additional heat exchanger 34 when the measured pressure becomes greater than a pressure threshold. On the other hand, the control unit actuates the displacement of the three-way valve 37 to its second position in which it conducts the flow of gas from the vaporization chamber 14 to the bypass line 36 when the measured pressure is below a second pressure threshold. This second pressure threshold can be identical to the first pressure threshold or lower than the latter which makes it possible to generate a hysteresis

phenomenon making it possible to avoid an untimely switchover of the three-way valve 37.

As an example, the first pressure threshold likely to lead to a displacement of the three-way valve 37 from its second position to its first position in which it conducts the flow of gas from the vaporization chamber 14 to the additional heat exchanger 34 is of the order of 1200 mbar and the second pressure threshold likely to lead to a displacement of the three-way valve 37 from its first position to its second position in which it conducts the flow of gas from the vaporization chamber 14 to the bypass line 36 is of the order of 1050 mbar. Thus, such an operation makes it possible to ensure that the pressure of the gaseous phase remains within a determined pressure band. This is particularly advantageous when the tank is a membrane tank whose sealing membranes are likely to be damaged in case of significant overpressures or depressurizations.

Figure 14 represents a vaporization device 4 which differs from the embodiment of figure 13 only in that the second three-way coupling coupling the bypass line 36 to the outlet circuit 7 and the additional heat exchanger 34 to the outlet circuit 7 is not equipped with a three-way valve 38, which makes it possible to simplify it.

The vaporization device represented in figure 15 differs from the embodiment of figure 14 only in that the first three-way coupling making it possible to couple the vaporization chamber 14 to the bypass line 36 and to the additional heat exchanger 34 is not equipped with a three-way valve 37. However, the bypass line 36 is equipped with a valve 39 that makes it possible to selectively allow or prevent the passage of the gas flow through the bypass line 36. Thus, when the valve 39 is closed, the flow of gas is conducted to the additional heat exchanger 34 whereas, when it is open, the flow of gas is conducted preferentially through the bypass line 36 because of lower head losses through the bypass line 36 than through the additional heat exchanger 34.

The vaporization device 14 of figure 16 differs from the embodiments of figures 13 to 15 in that it comprises a bypass line 40 making it possible to divert, upstream of the vaporization chamber, all or part of the withdrawn flow in order to conduct it to the additional heat exchanger 34 without it passing through the vaporization chamber 14, the vaporization of all or part of the withdrawn gas flow

then being performed through the additional heat exchanger 34, the latter being in this case equipped with a head loss member. The bypass line 40 is, on the one hand, coupled to the inlet circuit 5, upstream of the vaporization chamber, and on the other hand, coupled to the inlet of the additional heat exchanger 34.

5 The bypass line 36 is equipped with a valve 41 associated with a flow meter 42 making it possible to regulate the liquefied gas flow rate which is directed to the additional heat exchanger 34 without passing through the vaporization chamber 14.

 Similarly, the duct linking the outlet of the vaporization chamber 14 to the
10 inlet of the additional heat exchanger 34 is also equipped with a valve 43 associated with a flow meter 43 making it possible to regulate the flow rate of liquefied gas which is directed from the vaporization chamber 14 to the additional heat exchanger 34.

 Thus, such an arrangement therefore allows the vaporization chamber 14
15 and the additional heat exchanger 34 to operate in parallel. This parallel mode of operation is advantageous in that it makes it possible to increase the rate of cooling of the tank and thus makes it possible to rapidly reduce the pressure in the gaseous top of the tank when it exceeds a certain pressure threshold.

 According to an embodiment, the proportions of the part of the withdrawn
20 gas flow passing through the vaporization chamber 14 and that passing through the additional heat exchanger 34 without passing through the vaporization chamber 14 are determined as a function of the pressure of the gaseous phase.

 Figure 17 illustrates another variant embodiment in which the vaporization
device is equipped with two vacuum pumps 9, 45. One of the vacuum pumps 9 is
25 coupled to the bypass line 36 and thus makes it possible to control the gas flow rate circulating through the vaporization chamber 14 whereas the other vacuum pump 45 is coupled to the outlet of the additional heat exchanger 34 and thus makes it possible to control the gas flow rate circulating through the additional heat exchanger 34. Such an arrangement offers a greater flexibility of operation by
30 making it possible to totally independently control the flow rates of gas circulating through the vaporization chamber 14 and the additional heat exchanger 34.

 Referring to figure 11, a sectional view of a methane tanker 70 equipped with such a liquefied natural gas storage and cooling installation can be observed.

Figure 11 shows a tight and insulated tank 71 of generally prismatic form mounted in the double hull 72 of the ship. The wall of the tank 71 comprises a primary tight barrier intended to be in contact with the liquefied natural gas contained in the tank, a secondary tight barrier arranged between the primary tight barrier and the double
 5 hull 72 of the ship, and two insulating barriers arranged respectively between the primary tight barrier and the secondary tight barrier and between the secondary tight barrier and the double hull 72.

As is known per se, loading/offloading lines 73 arranged on the upper deck of the ship can be coupled, by means of appropriate connectors, to a maritime or
 10 port terminal to transfer a liquefied natural gas cargo from or to the tank 71.

Figure 11 also represents an example of maritime terminal comprising a loading and offloading station 75, a submarine duct 76 and an onshore installation 77. The loading and offloading station 75 is a fixed off-shore installation comprising a mobile arm 74 and a tower 78 which supports the mobile arm 74. The mobile arm
 15 74 bears a bundle of insulated flexible pipes 79 that can be connected to the loading/offloading lines 73. The orientable mobile arm 74 adapts to all the methane tanker templates. A link duct not represented extends inside the tower 78. The loading and offloading station 75 makes it possible to load and offload the methane tanker 70 from or to the onshore installation 77. The latter comprises liquefied gas
 20 storage tanks 80 and link ducts 81 linked by the submarine duct 76 to the loading or offloading station 75. The submarine duct 76 makes it possible to transfer liquefied gas between the loading or offloading station 75 and the onshore installation 77 over a great distance, for example 5 km, which makes it possible to keep the methane tanker 70 at a great distance from the coast during the loading and offloading
 25 operations.

To generate the pressure necessary to the transfer of the liquefied gas, onboard pumps in the ship 70 and/or pumps with which the onshore installation 77 is equipped and/or pumps with which the loading and offloading station 75 is equipped are implemented.

30 Although the invention has been described in conjunction with several particular embodiments, obviously it is in no way limited thereto and it includes all the technical equivalents of the means described and their combinations if the latter fall within the scope of the invention.

The use of the verb "comprise" or "include" and the conjugated forms thereof does not exclude the presence of elements or steps other than those stated in a claim. The use of the indefinite article "a" or "an" for an element or a step does not, unless otherwise stipulated, exclude the presence of a plurality of such
5 elements or steps.

In the claims, any reference symbol between brackets should not be interpreted as a limitation on the claim.

CLAIMS

1. A vaporization device (4) for cooling a liquefied gas chosen from liquefied natural gas, ethane and liquefied petroleum gas, said vaporization device (1) comprising:

- a vaporization chamber (14) arranged in the interior space of a container (2, 19) intended to be filled with liquefied gas (3), the vaporization chamber (14) comprising heat exchange walls (6) allowing an exchange of heat between an interior space of the vaporization chamber (14) and a liquefied gas (3) present in the interior space of the container (2, 19);

- an inlet circuit (5) comprising an intake emerging in the interior space of the container (2, 19) for withdrawing a flow of liquefied gas in liquid phase from the container (2, 19) and a plurality of head loss members emerging in the interior space of the vaporization chamber (14) in order to expand the withdrawn gas flow and formed from spray nozzles (13) capable of spraying the liquefied gas inside the vaporization chamber (14);

- an outlet circuit (7) arranged to evacuate the withdrawn gas flow, in gaseous phase from the vaporization chamber (14) to a vapor phase gas usage circuit (8); said outlet circuit (7) comprising a vacuum pump (9) capable of sucking the gas flow into the vaporization chamber (14), of discharging it to the vapor phase gas usage circuit (8) and of maintaining an absolute pressure lower than atmospheric pressure in the vaporization chamber (14).

2. The device as claimed in claim 1, in which the vacuum pump (9) is capable of placing the gas flow circulating in the vaporization chamber (14) under an absolute pressure of between 120 and 950 mbar.

3. The device as claimed in claim 1 or 2, in which the inlet circuit (5) comprises a pressure regulator (17) upstream of the head loss member (13).

4. The device as claimed in any one of claims 1 to 3, in which the inlet circuit (5) comprises, upstream of the head loss member (13), an additional pump (33) capable of sucking the flow of liquefied gas in liquid phase and of generating a discharge pressure greater than the maximum hydrostatic pressure likely to be reached in the interior space of the container (2, 19) at the intake of the inlet circuit (5).

5. The device as claimed in claim 4, in which the inlet circuit (5) further comprises a pressure regulator (17) arranged downstream of the additional pump (33) capable of limiting the pressure of the liquefied gas discharged by the additional pump (33) in the inlet duct (5) to a threshold pressure lower than the discharge pressure of the additional pump (33).

6. The device as claimed in any one of claims 1 to 5, in which the heat exchange walls (6) comprise fins (15), intended to augment the exchange surface of the vaporization chamber (14).

7. The device as claimed in any one of claims 1 to 6, comprising a device (24) for recovering and evacuating a heavy fraction of the withdrawn liquefied gas, associated with the vaporization chamber (14).

8. The device as claimed in claim 7, in which the vaporization chamber (14) has a slope and in which the device (24) for recovering and evacuating a heavy fraction of the liquefied gas comprises a receptacle (25) linked to a low point of the vaporization chamber (14) so as to collect the heavy fraction by gravity.

9. The device as claimed in claim 8, in which the receptacle (25) is coupled to the vaporization chamber (14) by a valve, a duct, a non-return valve (31) or a trap (29).

10. The device as claimed in claim 8 or 9, in which the device (24) for recovering and evacuating a heavy fraction of the liquefied gas further comprises an evacuation duct (26) linked to the receptacle (25), the evacuation duct (26) extending from the receptacle (25) to the container (2, 19) or to a heavy fraction conditioning device.

11. The device as claimed in claim 10, in which the evacuation duct (26) is equipped with a pump (27) for discharging the heavy fraction in liquid phase through the evacuation duct (26).

12. The device as claimed in claim 10, in which the device (24) for recovering and evacuating a heavy fraction of the liquefied gas further comprises a heating device capable of heating an interior space of the receptacle (25) to vaporize the heavy fraction; the evacuation duct (26) being capable of evacuating the heavy fraction in vapor phase.

13. The device as claimed in one of claims 10, in which the evacuation duct (26) is linked to the receptacle (25) via a valve or a non-return valve (30) and in which the interior space of the receptacle (25) is connected with the outlet circuit (7) of the device, the outlet circuit (7) being coupled to a fluid supply device via a Y-coupling in order to be able to discharge fluid through the outlet circuit (7) to the receptacle (25) so as to discharge the heavy fraction contained in the receptacle (25) to the evacuation duct (26).

14. The device as claimed in any one of claims 1 to 13, further comprising an additional heat exchanger (34) which is coupled upstream to the vaporization chamber (14) and downstream to the outlet circuit (7), said additional exchanger (34) being arranged in an

upper portion of the interior space of the container (2) intended to be filled at least partially with liquefied gas (3).

15. The device as claimed in claim 14, comprising a first bypass line (36), a first three-way coupling coupling the vaporization chamber (14) to the additional heat exchanger (34) and to the first bypass line (36) and a valve (37, 39) capable of selectively allowing or preventing the passage of the gas flow withdrawn from the vaporization chamber (14) to the first bypass line (36).

16. The device as claimed in claim 14 or 15, comprising a second bypass line (40) which is, on the one hand, coupled to the inlet circuit (5), upstream of the head loss member (13), and, on the other hand, coupled to the additional heat exchanger (34), in order to conduct at least a part of the withdrawn liquefied gas flow from the inlet circuit to the second bypass line (40), the device further comprising regulation means (40, 42, 43, 44) capable of regulating the flow rates of gas flows circulating respectively through the vaporization chamber (14) and through said second bypass line (40).

17. A liquefied gas storage and cooling installation comprising a container (2, 19) having an interior space and a vaporization device as claimed in any one of claims 1 to 16, the vaporization chamber (14) of said vaporization device being arranged in the interior space of said container (2, 19).

18. The installation as claimed in claim 17, in which the container (2, 19) is a tight and thermally insulating tank.

19. The installation as claimed in claim 17 or 18, in which the container is a tight and thermally insulating ancillary tank (19), the installation (1) further comprising a tight and thermally insulating main tank (20), a delivery duct (21) and a return duct (22) linking the main tank (20) and the ancillary tank (19) and a pump (23) capable of circulating liquefied gas between the main tank (20) and the ancillary tank (19) through the delivery duct (21) and the return duct (22).

20. The installation as claimed in any one of claims 17 to 19, in which the container (2, 19) is filled with a liquefied combustible gas chosen from liquefied natural gas, ethane and liquefied petroleum gas.

21. A method for cooling a liquefied gas contained in the interior space of a container (2, 19), the liquefied gas being chosen from liquefied natural gas, ethane and liquefied petroleum gas, the cooling method comprising:

- withdrawing a flow of liquefied gas in the container (2, 19) containing a quantity of liquefied

gas having to be cooled and conducting it to a vaporization chamber (14) arranged in the interior space of the container (2, 19) through a plurality of head loss members emerging in the interior space of the vaporization chamber (14) and formed from spray nozzles (13) capable of spraying the liquefied gas inside the vaporization chamber (14);

- 5 - generating an absolute pressure lower than atmospheric pressure inside the vaporization chamber (14);
- effecting a heat exchange through the walls (6) of the vaporization chamber (14) between the gas flow withdrawn and expanded in the vaporization chamber (14) and the liquefied gas (3) contained in the container (2, 19) so as to vaporize the withdrawn gas flow by absorbing
- 10 calories from the liquefied gas (3) contained in the container (2, 19); and
- conducting the withdrawn gas flow in vapor phase to a vapor phase gas usage circuit (8).

22. The method as claimed in claim 21, in which an absolute pressure lying between 120 and 950 mbar, preferably lying between 650 and 850 mbar, is maintained inside the vaporization chamber (14).

- 15 23. The method as claimed in claim 21 or 22, in which the liquefied gas is stored in the interior space of the container (2) in a state of two-phase equilibrium and has a lower liquid phase and an upper gaseous phase (35) and in which the gas flow withdrawn from the vaporization chamber (14) is conducted to an additional exchanger (34) in contact at least partially with the upper gaseous phase (35) in order to effect a heat exchange between the
- 20 withdrawn gas flow and the upper gaseous phase (35) before conducting the withdrawn gas flow to the vapor phase gas usage circuit (8).

- 24. The method as claimed in claim 23, in which the vaporization chamber (14) is coupled to the additional heat exchanger (34) and to a bypass line (36) making it possible to circumvent the additional heat exchanger (35) via a first three-way coupling, a valve (37, 39)
- 25 being capable of selectively allowing or preventing the passage of the withdrawn gas flow to the bypass line (36) and in which said valve (37, 39) is controlled in order to allow or prevent the passage of the withdrawn gas flow to the bypass line (36) as a function of a variable representative of the pressure of the upper gaseous phase (35).

- 25. The method as claimed in any one of claims 21 to 24, in which the liquefied gas
- 30 is stored in the interior space of the container (2) in a state of two-phase equilibrium and has a lower liquid phase and an upper gaseous phase (35) and in which a flow of liquefied gas is withdrawn from the container and it is conducted to an additional heat exchanger (34) at least partially in contact with the upper gaseous phase (35) in order to effect a heat exchange between said withdrawn gas flow and the upper gaseous phase (35).

26. A ship (70) comprising an installation (1) as claimed in any one of claims 17 to 20 and in which the vapor phase gas usage circuit (8) is an energy production unit.

27. A method for loading or offloading a ship (70) as claimed in claim 26, in which a fluid is routed through insulated lines (73, 79, 76, 81) from or to a floating or onshore storage
5 installation (77) to or from a tank (71) of the ship.

28. A transfer system for a fluid, the system comprising a ship (70) as claimed in claim 26, insulated lines (73, 79, 76, 81) arranged so as to link the tank (71) installed in the hull of the ship to a floating or onshore storage installation (77) and a pump for driving a fluid
10 tank of the ship.