

is thus able to draw in, through the conduit 10, a stream of gas in the vapor phase which is present in the inner space of the vessel 2 and to pump it toward the circuit for use of gas in the vapor phase 13. In the embodiment represented, the removal circuit 9 comprises a check valve 19 or gate, situated upstream or downstream from the vacuum pump 12 and thus avoiding a return of the stream of gas in the vapor phase to the inner space of the vessel 2.

The vacuum pump 12 is able to generate, in the vapor phase disposed in the upper portion of the inner space of the vessel 2, a pressure P_1 less than the atmospheric pressure. Thus, when the vacuum pump 12 is placed in operation and draws in a stream of gas in the vapor phase from the interior of the inner space of the vessel 2 and pumps it toward the circuit for use of gas in the vapor phase 13, the vacuum pump 12 also generates a pressure P_1 less than the atmospheric pressure in the vapor phase of the inner space of the vessel.

Hence, the vapor phase having been placed at a pressure P_1 less than the atmospheric pressure, the vaporization of the liquefied gas 8 present in the vessel 2 is promoted at the liquid/vapor interface, while the liquefied gas 8 stored in the vessel 2 is placed in a state of two-phase liquid-vapor equilibrium in which the liquefied gas has a temperature less than the liquid-vapor equilibrium temperature of said liquefied gas at atmospheric pressure.

These phenomena are explained below in connection with figure 2, which represents a liquid-vapor equilibrium diagram for methane. This diagram represents a region, denoted L, in which the methane is present in the liquid phase, and a region, denoted V, in which the methane is present in the vapor phase, as a function of the temperature represented along the ordinate axis and the pressure along the abscissa axis.

The point P_{11} represents a state of two-phase equilibrium corresponding to the state of the methane stored in a vessel at the atmospheric pressure and at a temperature of around -162°C . When the storage pressure of the methane in the vessel has fallen below the atmospheric pressure, for example, to an absolute pressure of around 500 mbars, the equilibrium of the methane is shifted to the left, up to the point P_{12} . Once at equilibrium, the methane so expanded thus undergoes a decrease in temperature of around 7°C , while a portion of the methane in liquid phase evaporates, subtracting from the liquid methane stored in the vessel the heat needed for its vaporization. Hence, by placing a liquefied gas at an absolute pressure less than the atmospheric pressure, the liquefied gas is maintained in a thermodynamically undercooled state, such that a return to a storage in the vessel at atmospheric pressure or its further transfer to a vessel at atmospheric pressure may be done by maintaining a low rate of evaporation of the liquefied gas, even a zero rate, thus preventing or reducing phenomena of flash vaporization at the start of the transfer.

The vacuum pump 12 is a cryogenic pump, that is, a pump able to sustain cryogenic temperatures less than -150°C . It should further comply with the standard ATEX, that is, be designed to prevent any risk of explosion.

CLAIMS

1. A method for cooling of a liquefied gas (8) stored in the inner space of a sealed and thermally insulated vessel (2), said liquefied gas (8) being stored in the inner space of the vessel (2) in a state of two-phase liquid-vapor equilibrium and having a lower liquid phase and an upper vapor phase separated by an interface, said method involving the steps of:
 - drawing by means of a vacuum pump a stream of gas in vapor phase in a zone of the vapor phase in contact with a zone of the interface, said step of drawing a stream of gas in vapor phase generating in said zone of the vapor phase a pressure P1 of less than the atmospheric pressure such that vaporization of the liquid phase is promoted in the area of the zone of the interface and the liquefied gas in contact with the zone of the interface is placed in a state of two-phase liquid-vapor equilibrium in which the liquefied gas has a temperature less than the liquid-vapor equilibrium temperature of said liquefied gas at atmospheric pressure; and
 - guiding the drawn stream of gas in vapor phase toward a circuit for use of gas in vapor phase (13).
2. The method for cooling as claimed in claim 1, wherein the pressure P1 is greater than 120 mbars absolute.
3. The method for cooling as claimed in claim 1 or 2, wherein said vacuum pump (12) is controlled as a function of a flow rate setpoint generated by the circuit for use of gas in vapor phase (13).
4. The method for cooling as claimed in claim 1 or 2, wherein the pressure is measured in the zone of the vapor phase and said vacuum pump (12) is controlled as a function of a pressure setpoint and the measured pressure.
5. The method for cooling as claimed in any one of claims 1 to 4, wherein the pressure P1 is between 750 mbars and 980 mbars absolute.
6. The method as claimed in any one of claims 1 to 5, wherein the vessel (2) comprises a multilayered structure mounted on a carrier structure (4), the multilayered structure comprising a primary sealing membrane in contact (7) with the liquefied gas contained in the vessel and a primary thermally insulating barrier (6) disposed between the sealing membrane (7) and the carrier structure (4), said thermally insulating barrier (6) comprising insulating blocks and a gas phase, the method involving the step of maintaining the gas phase of the thermally insulating barrier (6) at a pressure P2 less than or equal to the pressure P1.
7. The method as claimed in claim 6, wherein the multilayered structure comprises, from the outside to the inside of the vessel (2), a secondary thermally insulating barrier (3) comprising insulating blocks resting against the carrier structure (4) and a gas phase, a secondary

sealing membrane (5) resting against the insulating blocks of the secondary thermally insulating barrier (3), the primary thermally insulating barrier (6) and the primary sealing membrane (7), the method involving the step of maintaining the gas phase of the primary thermally insulating barrier (7) and the gas phase of the secondary thermally insulating barrier (3) respectively at a pressure P2 and at
5 a pressure P3, said pressures P2 and P3 being less than or equal to the pressure P1.

8. The method as claimed in claim 7, wherein the pressure P3 is greater than or equal to the pressure P2.

9. The method as claimed in any one of claims 1 to 8, wherein the vessel (2) is filled with a liquefied fuel gas (8) chosen from among liquefied natural gas, ethane and liquefied
10 petroleum gas.

10. The method as claimed in any one of claims 1 to 9, wherein the vessel (2) is equipped with a vacuum bell jar (20) lodged in the inner space of the vessel (2) and comprising an upper portion disposed in the vapor phase and a lower portion immersed in the liquid phase and in which the zone of the vapor phase into which the stream of gas is drawn in the vapor phase is defined
15 by the upper portion of the vacuum bell jar (20).

11. The method as claimed in any one of claims 1 to 9, wherein the pressure P1 is generated in an upper portion of the vessel containing the entire vapor phase.

12. An installation for storage and cooling of a liquefied gas, comprising:
- a sealed and thermally insulated vessel (2) having an inner space designed to be filled with a
20 liquefied gas (8) stored in a state of two-phase liquid-vapor equilibrium such that the liquefied gas has a lower liquid phase and an upper vapor phase separated by an interface; and
- a circuit for removal of gas in the vapor phase (9) comprising:
- an intake (11) emerging into the inner space of the vessel (2) above a maximum fill height of the vessel so that when the vessel is full it empties into a zone of the vapor phase in
25 contact with a zone of the interface; and
- a first vacuum pump (12), the first vacuum pump (12) and the circuit for removal of gas in the vapor phase (9) being configured to draw a stream of gas in vapor phase present in the zone of the vapor phase through the intake (11), to pump this to a circuit for use of gas in the vapor phase (13), and to maintain in the zone of the vapor phase a pressure P1 less than
30 the atmospheric pressure, such that vaporization of the liquid phase is promoted in the area of the interface zone and the liquefied gas in contact with the zone of the interface is placed in state of a two-phase liquid-vapor equilibrium in which the liquefied gas has a temperature less than the liquid-vapor equilibrium temperature of said liquefied gas at atmospheric pressure.

35 13. The installation as claimed in claim 12, comprising a sensor to measure the flow rate, able to provide a signal representative of a flow rate of vapor drawn in through the intake

and pumped to the circuit for use and a control device (18) configured to control the first vacuum pump (12) as a function of the signal representative of the flow rate of vapor and a flow rate setpoint generated by the circuit for use of gas in the vapor phase (13).

14. The installation as claimed in claim 12, comprising a pressure sensor able to
5 provide a signal representative of the pressure prevailing in the inner space of the vessel above the maximum fill height and a control device (18) able to control the first vacuum pump (12) as a function of the signal representative of the pressure and a pressure setpoint.

15. The installation as claimed in any one of claims 12 to 14, further comprising a circuit for use of gas in the vapor phase (13) comprising energy production equipment.

10 16. The installation as claimed in any one of claims 12 to 15, wherein the vessel (2) comprises a multilayered structure mounted on a carrier structure (4), the multilayered structure comprising a sealing membrane (7) in contact with the liquefied gas (8) contained in the vessel (2) and a thermally insulating barrier (6) disposed between the sealing membrane (7) and the carrier structure (4), and comprising insulating blocks and a gas phase, the installation furthermore comprising a
15 second vacuum pump (16) designed to maintain the gas phase of the thermally insulating barrier (6) at a pressure P2 less than or equal to the pressure P1.

17. The installation as claimed in any one of claims 12 to 15, wherein the vessel (2) comprises a multilayered structure mounted on a carrier structure (4), the multilayered structure comprising, from the outside to the inside of the vessel (2), a secondary thermally insulating barrier
20 (3) comprising insulating blocks resting against a carrier structure (4) and a gas phase, a secondary sealing membrane (5) resting against the insulating blocks of the secondary thermally insulating barrier (3), a primary thermally insulating barrier (6) comprising insulating elements resting against the secondary sealing membrane (5) and a gas phase and a primary sealing membrane (7) designed to be in contact with the liquefied gas (8) contained in the vessel (2), the installation furthermore
25 comprising a second vacuum pump (16) designed to maintain the gas phase of the primary thermally insulating barrier (6) at a pressure P2 less than or equal to the pressure P1 and a third vacuum pump (14) designed to maintain the gas phase of the secondary thermally insulating barrier (3) at a pressure P3 less than or equal to the pressure P1.

18. The installation as claimed in any one of claims 12 to 17, wherein the vessel
30 is equipped with a vacuum bell jar (20) lodged in the inner space of the vessel (2) and comprising an upper portion designed to be placed in contact with the vapor phase of the liquefied gas stored in the inner space of the vessel and a lower portion designed to be immersed in the liquid phase of the liquefied gas stored in the inner space of the vessel and in which the intake (11) of the circuit for removal of gas in vapor phase empties into the interior of the upper portion of the vacuum bell jar
35 (20).

19. The installation as claimed in claim 18, comprising a pressure sensor able to provide a signal representative of the pressure prevailing in the upper portion of the vacuum bell jar (20).

20. A ship (70) or off-shore liquefaction equipment, comprising an installation
5 (1) as claimed in any one of claims 12 to 19.

21. A method for loading or unloading of a ship (70) as claimed in claim 20, wherein a fluid is routed through insulated conduits (73, 79, 76, 81) from or to a floating or land-based storage installation (77) to or from a vessel (71) of the ship (70).

22. A system of transfer for a fluid, the system comprising a ship (70) as claimed
10 in claim 20, insulated conduits (73, 79, 76, 81) disposed to connect the vessel (71) installed in the hull of the ship to a floating or land-based storage installation (77), and a pump to drive a fluid through the insulated conduits from or to the floating or land-based storage installation to or from the vessel of the ship.