

Method and system for inerting a wall of a liquefied fuel gas-storage tank

Technical field

The invention relates to the inerting of a wall of an impermeable and thermally insulating tank intended to contain a liquefied fuel gas.

The invention may in particular apply to the inerting of walls of membrane tanks that are used for storing liquefied natural gas (LNG).

Technological background

Impermeable and thermally insulating tanks for storing liquefied natural gas are known that comprise a tank wall having successively, in the direction of the thickness, from the inside to the outside of the tank, a primary impermeable membrane intended to be in contact with the liquefied natural gas, a primary thermally insulating barrier, a secondary impermeable membrane, a secondary thermally insulating barrier and a load-bearing structure defining the general shape of the tank.

The impermeable membranes of such a tank may have leaks that lead to the passage of liquefied natural gas from the inside of the tank to the primary and secondary thermally insulating barriers. However, when a fuel gas is the presence of an oxidizing gas and when the concentration of fuel gas is within a concentration range between its lower explosive limit (LEL) and its upper explosive limit (UEL) and when the oxidizing gas is within an appropriate concentration range, the fuel gas is capable of igniting and exploding.

Therefore, in order to avoid accidents, it is known to maintain the thermally insulating barriers under an inert atmosphere by circulating nitrogen within these barriers. Thus, the fuel and oxidizing gases, which could be present in the thermally insulating barriers, are diluted such that the explosive conditions are not reached. Provision is also made to equip the tank with a gas analyzer that makes it possible to measure a concentration of fuel gas within the thermally insulating barrier in order to detect a leak of liquefied natural gas through the primary and/or secondary impermeable barriers.

It is furthermore known to maintain the gas phase of one and/or the other of the thermally insulating barriers under an absolute pressure lower than the ambient

atmospheric pressure, that is to say at a negative relative pressure, in order to increase the insulating property of said thermally insulating barriers. Such a process is for example described in French patent application FR2535831.

However, most gas analyzers are not capable of providing reliable measurements at low pressure. Hence, the pressure inside the thermally insulating barriers must be maintained above a minimum pressure, generally of the order of 80 kPa, so that the inert nature of the thermally insulating barrier can be reliably monitored. Similarly, the flow rates for circulation of gas inside the thermally insulating barriers must also be maintained above a minimum flow rate.

Thus, it is not possible to reliably monitor the inert nature of a thermally insulating barrier when it is maintained at low pressure.

Summary

One idea at the root of the invention is to provide a process and a system for inerting a wall of a tank intended to contain a liquefied fuel gas that are reliable and that make it possible to increase the insulating property of the tank.

According to one embodiment, the invention provides a process for inerting a wall of an impermeable and thermally insulating tank intended to contain a liquefied fuel gas, wherein the wall has a multilayer structure comprising two impermeable barriers and one thermally insulating barrier positioned between the two impermeable barriers, said thermally insulating barrier comprising insulating solid materials and a gas phase, said process making provision for:

- implementing a first inerting mode wherein the gas phase of the thermally insulating barrier is placed under a negative relative pressure P_1 lower than a threshold pressure P_s , said threshold pressure P_s being lower than a flammability limit pressure P_i of the fuel gas;
- detecting, during the first inerting mode, whether the pressure of the gas phase of the thermally insulating barrier exceeds said threshold pressure P_s ;
- switching from the first inerting mode to a second inerting mode in response to the detection of a pressure of the gas phase of the thermally insulating barrier that exceeds the threshold pressure P_s , the second inerting mode making provision for flushing the thermally insulating barrier with an inert gas.

Thus, the first inerting mode makes it possible, on the one hand, to ensure the inert nature of the gas phase present in the thermally insulating barrier since it is

placed at a pressure lower than the flammability limit pressure of the fuel gas and, on the other hand, to increase the insulating property of the tank by maintaining said thermally insulating barrier under reduced pressure. Furthermore, the inert nature is reliably ensured since, in the event of loss of impermeability of one of the impermeable membranes preventing a pressure lower than the flammability pressure from being maintained, the process makes provision, as soon as a threshold pressure P_s is reached, for switching to a second operating mode, in which the thermally insulating barrier is flushed by an inert gas in order to sufficiently dilute the fuel and/or oxidizing gases so that explosive conditions are not reached.

It should be noted that, within the meaning of the present description, a process for inerting a thermally insulating barrier is understood to mean a process that makes it possible to ensure that the gas phase contained in said thermally insulating barrier is not placed under explosive or flammable conditions of a fuel gas.

According to embodiments, such a process may comprise one or more of the following features:

- in the first inerting mode, a control device starts a pumping device in order to place the gas phase of the thermally insulating barrier under a setpoint negative relative pressure P_1 ;
- the threshold pressure P_s is lower than 17 000 Pa;
- the threshold pressure P_s is lower than the partial pressure of said fuel gas, at atmospheric pressure, in a gas mixture comprising a concentration of the fuel gas corresponding to the lower explosive limit of said fuel gas in air, at 25°C;
- the threshold pressure P_s is between 20% and 35% of the partial pressure of said fuel gas, at atmospheric pressure, in a gas mixture comprising a concentration of the fuel gas corresponding to the lower explosive limit of said fuel gas in air, at 25°C;
- the threshold pressure P_s is 30% of the partial pressure of said fuel gas, at atmospheric pressure, in a gas mixture comprising a concentration of the fuel gas corresponding to the lower explosive limit of said fuel gas in air, at 25°C;
- the threshold pressure P_s is lower than the partial pressure of air, at atmospheric pressure, in a gas mixture comprising a concentration of air corresponding to a concentration of oxygen equal to a minimum concentration of oxygen enabling the flammability of the fuel gas;

- in the second inerting mode, the thermally insulating barrier is flushed with an inert gas, at atmospheric pressure;
- the fuel gas is selected from the group consisting of methane, ethane, n-butane, propane, ethylene and mixtures thereof;
- 5 - the tank is intended for storing fuel gas in the liquid state;
- the fuel gas is stored in the tank at a temperature between -163°C and 0°C , and more particularly at a temperature of the order of -163°C in the tank when the fuel gas is a liquefied natural gas stored at atmospheric pressure;
- the inert gas is selected from the group consisting of dinitrogen, helium, argon and mixtures thereof;
- 10 - one of the impermeable barriers consists of a load-bearing structure, the other impermeable barrier consists of a secondary metallic membrane, and the thermally insulating barrier is a secondary thermally insulating barrier, the multilayer structure additionally comprising a primary metallic membrane intended to be in contact with
- 15 the fuel gas stored inside the tank and a primary thermally insulating barrier positioned between the primary metallic membrane and the secondary metallic membrane, said primary thermally insulating barrier comprising insulating solid materials and a gas phase, the process additionally making provision for:
 - o implementing a first inerting mode of the primary thermally insulating barrier wherein a control device starts a pumping device in order to place the gas phase of the primary thermally insulating barrier under a setpoint negative relative pressure $P1'$ lower than a threshold pressure Ps' , said threshold pressure Ps' being lower than the flammability limit pressure Pi of the fuel gas;
 - 20 o detecting, during the first inerting mode of the primary thermally insulating barrier, whether the pressure of the gas phase in said primary thermally insulating barrier exceeds said threshold pressure Ps' ;
 - 25 o switching from the first inerting mode to a second inerting mode of the primary thermally insulating barrier in response to the detection of a pressure of the gas phase of the primary thermally insulating barrier that exceeds the threshold pressure Ps' , the second inerting mode making provision for flushing the primary thermally insulating barrier with an inert gas;
 - 30

- the threshold pressure P_s is variable and a first value is assigned to the threshold pressure P_s while the first inerting mode of the primary thermally insulating barrier is implemented and a second value is assigned to the threshold pressure P_s in response to the detection of a pressure of the gas phase of the primary thermally insulating barrier that exceeds the threshold pressure P_s' .

According to one embodiment, the invention also provides a system for inerting a wall of an impermeable and thermally insulating tank intended to contain a liquefied fuel gas, wherein the wall has a multilayer structure comprising two impermeable barriers and one thermally insulating barrier positioned between the two impermeable barriers, said thermally insulating barrier comprising insulating solid materials and a gas phase, the inerting system comprising:

- a pumping device arranged in order to place the gas phase of the thermally insulating barrier under a negative relative pressure P_1 lower than a threshold pressure P_s , said threshold pressure P_s being lower than a flammability limit pressure P_i of the fuel gas;
- a pressure sensor capable of providing a signal representative of the pressure of the gas phase inside the thermally insulating barrier;
- inert gas injection equipment connected, on one side, to an inert gas storage reservoir and/or to an inert gas generator, and, on the other side, to a supply pipe for supplying inert gas to the inside of the thermally insulating barrier; and
- a control unit capable of:
 - o detecting whether the pressure of the gas phase of the thermally insulating barrier exceeds said threshold pressure P_s ; and of
 - o generating a signal for starting the inert gas injection equipment in response to the detection of a pressure of the gas phase of the thermally insulating barrier that exceeds the threshold pressure P_s .

According to embodiments, such an inerting system may comprise one or more of the following features:

- the inert gas injection equipment is connected to a dinitrogen generator;
- the inerting system comprises a gas analyzer for measuring a concentration of fuel gas in the gas phase.

According to one embodiment, the invention also provides an impermeable and thermally insulating tank intended to contain a liquefied fuel gas, comprising a wall having a multilayer structure comprising two impermeable barriers and one

thermally insulating barrier positioned between the two impermeable barriers, said thermally insulating barrier comprising insulating solid materials and a gas phase, and an aforementioned inerting system.

5 In one embodiment, one of the impermeable barriers consists of a load-bearing structure and the other impermeable barrier consists of a secondary metallic membrane, the multilayer structure additionally comprising a primary metallic membrane intended to be in contact with the fuel gas stored inside the tank and a thermally insulating barrier positioned between the primary metallic membrane and the secondary metallic membrane.

10 Such a tank may be part of an onshore storage facility, for example for storing LNG or may be installed on a coastal or deep-water floating structure, in particular a methane tanker, a floating storage and regasification unit (FSRU), a floating production storage and offloading (FPSO) unit and others.

15 According to one embodiment, a tanker for transporting a fluid comprises an aforementioned tank.

According to one embodiment, the invention also provides a process for loading or offloading such a tanker, wherein a fluid is conveyed through insulated pipes from or to a floating or onshore storage facility to or from the tank of the tanker.

20 According to one embodiment, the invention also provides a cold liquid product transfer system, the system comprising the aforementioned tanker, insulated pipes arranged so as to connect the tank installed in the hull of the tanker to a floating or onshore storage facility and a pump in order to drive a fluid through the insulated pipes from or to the floating or onshore storage facility to or from the
25 tank of the tanker.

Brief description of the figures

The invention will be better understood, and other objectives, details, features and advantages thereof will become more clearly apparent, during the following description of several particular embodiments of the invention, given solely
30 by way of nonlimiting illustration, with reference to the appended drawings.

- **Figure 1** is a schematic view of a tank equipped with an inerting system.

- **Figure 2** is a curve illustrating the influence of the pressure and of the temperature on the flammability limits of methane in air.
- **Figure 3** is a schematic view representing a cutaway tank of a methane tanker that may be equipped with an inerting system and a terminal for loading/offloading this tank.

Detailed description of embodiments

With reference to figure 1, a tank 1 intended for storing a fuel gas has been represented schematically. Each wall of the tank 1 comprises a multilayer structure comprising, from the outside toward the inside of the tank 1, a load-bearing structure 2 that defines the general shape of the tank 1, a secondary thermally insulating barrier 3 that comprises insulating elements resting against the load-bearing structure 2, a secondary impermeable membrane 4, a primary thermally insulating barrier 5 that comprises insulating elements resting against the secondary impermeable membrane 4 and a primary impermeable membrane 6 intended to be in contact with the liquefied fuel gas contained in the tank 1.

The load-bearing structure 2 may in particular be a self-supporting metal sheet and/or be formed by the hull or the double hull of a tanker.

The thermally insulating barriers 3, 5 comprise insulating solid materials and a gas phase. According to one embodiment, the thermally insulating barriers 3, 5 are formed from heat-insulating boxes, not illustrated. The boxes comprise a base panel and a cover panel, for example made of plywood, and a plurality of spaced elements inserted between the base and cover panels. Compartments for housing a heat-insulating packing are made between the spaced elements. The insulating packing may be made from any material having suitable thermal insulation properties. By way of example, the heat-insulating packing is selected from materials such as perlite, glass wool, polyurethane foam, polyethylene foam, polyvinyl chloride foam, aerogels or others.

The primary and secondary impermeable membranes 6, 4 consist for example of a continuous layer of metal strakes with raised edges, said strakes being welded by their raised edges to parallel weld supports, fastened to the cover of the boxes.

The primary and secondary impermeable membranes 6, 4 are impermeable to gases and liquids. The load-bearing structure 2 is also impermeable. Hence, within the meaning of the present description and claims, the term "impermeable barrier" covers both the impermeable membranes 4, 6 and the load-bearing structure 2. Thus, the secondary thermally insulating barrier 3 is arranged in an impermeable space which is isolated from the ambient pressure, on the one hand by a first impermeable barrier consisting of the secondary impermeable membrane 4, and on the other hand by a secondary impermeable barrier consisting of the load-bearing structure 2.

The fuel gas is a liquefied gas, that is to say a chemical substance or a mixture of chemical substances that has been placed in a liquid phase at low temperature and that would be in a vapor phase under normal temperature and pressure conditions. The liquefied gas 3 may in particular be a liquefied natural gas (LNG), that is to say a gas mixture predominantly comprising methane and also one or more other hydrocarbons, such as ethane, propane, n-butane, i-butane, n-pentane, i-pentane and nitrogen in a small proportion. The liquefied natural gas is stored at atmospheric pressure at a temperature of around -162°C.

The fuel gas may also be ethane or a liquefied petroleum gas (LPG), that is to say a mixture of hydrocarbons resulting from the refining of petroleum essentially comprising propane and n-butane. The fuel gas may also be ethylene.

The storage temperatures at atmospheric pressure of the various fuel gases are collated in the table below:

Methane	-162°C
Ethane	- 88.5°C
Propane	- 42 °C
n-Butane	- 0.5 °C
Ethylene	-103.7

In order to avoid, due to leaks of liquefied natural gas through the impermeable membranes 4, 6 and/or of air through the load-bearing structure 2, a gas mixture being present in explosive proportions within the walls of the tank 1, these walls are subjected to an inerting process that will be described in detail below.

It should be noted that, in the embodiment described and represented, the inerting process more particularly aims to carry out the inerting of the secondary thermally insulating barrier 3.

The inerting process and system that will be described in detail below have the distinctive feature of being able to operate according to two distinct inerting modes.

According to a first inerting mode, the gas phase contained in the thermally insulating barrier 3 is maintained around a setpoint pressure P_1 lower than a flammability limit pressure P_i of the fuel gas. Specifically, a flammability limit pressure P_i exists below which a fuel gas is no longer flammable. The setpoint pressure P_1 is an absolute pressure lower than the ambient atmospheric pressure, that is to say a negative relative pressure.

Figure 2 illustrates, by way of example, the flammability limits of methane in air as a function of the pressure and the temperature. It is thus observed that the flammability limit pressure P_i of methane in air is, at 25°C, of the order of 130 mm of mercury, i.e. 17 331 Pa. Thus, irrespective of the proportions of fuel gas and oxygen in the gas phase of the thermally insulating barrier 3, this gas phase is not capable of igniting and exploding when it is placed at such a setpoint pressure P_1 , lower than the flammability limit pressure P_i of the fuel gas. This first inerting mode also has advantage of increasing the insulating property of the thermally insulating barrier 3.

By way of example, the table below represents the orders of magnitude of the flammability limit pressures in air at 25°C of various fuel gases.

Fuel gas	P_i
Methane	17 331 Pa
Ethane	26 600 Pa
Propane	28 600 Pa
Butane	26 600 Pa

In order to carry out such an inerting mode, the inerting system comprises a pumping device 7 connected by a pipe 8 to the thermally insulating barrier 3. The pumping device 7 comprises one or more vacuum pumps suitable for enabling the thermally insulating barrier 3 to be maintained under a low pressure, of the order of

several hundred or thousand pascals. The vacuum pumping device is for example a staged or cascaded assembly of vane pumps or Roots pumps.

The system also comprises a pressure sensor 9 that makes it possible to deliver a signal representative of the pressure of the gas phase inside the thermally insulating barrier 3. The pressure sensor 9 is connected to a pressure control device that makes it possible to control the pumping device 7 as a function of the setpoint pressure P1. The control device is capable of starting the pumping device 7 when the pressure measured by the pressure sensor 9 is greater than the setpoint pressure P1 and of shutting down the pumping device 7 when the pressure measured is lower than the setpoint pressure P1. The control device is advantageously endowed with hysteresis that makes it possible to improve the stability of the control. The control device may be chosen to be integrated into the pumping device 7 or to be integrated into a control unit 10 of the inerting system.

Furthermore, the inerting system is also suitable for operating in a second mode in which the inerting of the thermally insulating barrier 3 is carried out, at atmospheric pressure, by flushing with inert gas. This second inerting mode corresponds to a degraded operating mode which is in particular suitable when a loss of impermeability of one of the impermeable barriers 2, 4 bordering the thermally insulating barrier 3 occurs. Indeed, in such a case, the thermally insulating barrier 3 is no longer isolated from the ambient pressure and it thus becomes impossible to maintain a negative relative pressure lower than a threshold pressure Ps.

In order to implement this second inerting mode, the inerting system comprises inert gas injection equipment 11 that makes it possible to flush the thermally insulating barrier 3 with an inert gas. The injection equipment 11 comprises a pressurized inert gas reservoir 12 connected to an inert gas supply pipe 14 that opens into the thermally insulating barrier 3. The pressurized inert gas reservoir 12 is connected to the pipe 14 via a valve 16 that makes it possible to control the flow rate and/or the pressure for the injection of inert gas into the thermally insulating barrier 3. The size of the pressurized inert gas reservoir 12 must be sufficient so that, in the event of loss of impermeability of one and/or the other of the impermeable barriers 2, 4 bordering the secondary thermally insulating barrier 3, the injection equipment 11 is capable of ensuring a sufficient dilution of the fuel gas and/or of the oxidizing gas so as not to reach the explosive limit concentrations. The

reservoir 12 must in particular be capable of storing an amount of inert gas substantially equivalent to the amount of gas phase contained at atmospheric pressure in the thermally insulating barrier 3.

The inert gas is selected from the group consisting of dinitrogen, helium, argon and mixtures thereof. In one embodiment, the inert gas used is dinitrogen.

According to one embodiment of the invention that is not represented, the inerting system comprises an inert gas generator in addition to or as a replacement for the pressurized inert gas reservoir 12. The inert gas generator may in particular be a dinitrogen generator that enables dinitrogen to be extracted from the surrounding air.

Where appropriate, the pipe 14 may also be equipped with an optional, complementary pump 13 in order to carry out the injection of inert gas, in particular when the injection equipment is equipped with an inert gas generator.

The inerting system also comprises a control unit 10 connected to the pressure sensor 9, to the pumping device 7 and to the inert gas injection equipment 11. The control unit 10 in particular has the role of automatically triggering the second inerting mode when the first inerting mode can no longer be implemented under satisfactory safety conditions, due to a loss of impermeability of one and/or the other of the impermeable barriers 2, 4 bordering the thermally insulating barrier 3.

In order to do this, the control unit 10 is capable of receiving and processing the signal representative of the pressure of the gas phase of the thermally insulating barrier 3 generated by the pressure sensor 9. During the first inerting mode, the control unit 10 compares the pressure P of the gas phase inside the thermally insulating barrier 3 to a threshold pressure P_s , greater than the setpoint pressure P_1 . As soon as the pressure P of the gas phase exceeds the threshold pressure P_s , the control unit 10 automatically switches from the first inerting mode to the second inerting mode. In other words, the control unit 10 generates a signal for starting the inert gas injection equipment 11 and a signal for shutting down the pumping device 7. In addition, according to one embodiment, the control unit 10 is also capable of generating a warning signal, when an exceedance of the threshold pressure P_s is detected.

The threshold pressure P_s , and consequently the setpoint pressure P_1 of the pumping device 7, must be wisely chosen as a function of the nature of the fuel gas contained in the tank 1 in order to ensure the safety of the return of the gas phase to atmospheric pressure under the effect of the injection of inert gas. The threshold pressure P_s must specifically be defined so that, when a loss of impermeability occurs, the gas phase in the thermally insulating barrier 3 is not capable of comprising fuel gas and/or oxidizing gas in proportions that would be capable of being within the explosion range when the gas phase returns to atmospheric pressure under the effect of the injection of inert gas.

In order to do this, provision is made for the threshold pressure P_s to be lower than the partial pressure of the fuel gas, at atmospheric pressure, at a concentration corresponding to the lower explosive limit of said fuel gas in air, at 25°C.

By way of example, the lower flammability limit of methane is 5% by volume at atmospheric pressure (101 325 Pa) and at 25°C. The partial pressure of methane corresponding to a concentration, by volume, of 5% methane at atmospheric pressure is therefore around 5 066 Pa. In other words, should an amount of methane corresponding to the lower explosive limit of methane, at atmospheric pressure, constitute on its own the whole of the gas phase contained in the thermally insulating barrier 3, its pressure would be 5 066 Pa. Consequently, as long as, during the first inerting mode, the pressure P of the gas phase in the thermally insulating barrier 3 is lower than 5 066 Pa, there is no risk of the concentration of methane, once returned to atmospheric pressure of 101 325 Pa, reaching the lower explosive limit, considering a complete and instantaneous dilution of the fuel gas in nitrogen.

Advantageously, the threshold pressure P_s is selected by taking a safety margin relative to the pressure mentioned above, in particular in order to take into account the phenomena of non-homogeneous mixing of the gas phase in the thermally insulating barrier 3 and the time necessary for the injection of a sufficient amount of inert gas in order for the gas phase to return to atmospheric pressure.

Hence, a threshold pressure P_s between 20% and 35%, and preferably of the order of 30%, of the partial pressure of the fuel gas, at atmospheric pressure, at the concentration of the fuel gas corresponding to its lower explosive limit is chosen.

Therefore, in the case of a methane storage tank, a threshold pressure P_s between 1013 and 1773 Pa, and preferably of the order of 1520 Pa, will be chosen.

By way of example, the table below reproduces the lower flammability limits of various fuel gases and comprises the threshold pressure P_s values corresponding to 30% of the partial pressure of the fuel gases, at atmospheric pressure, at a concentration corresponding to their lower explosive limit.

Fuel gas	LEL (% by volume) in air and at 25°C	P_s (Pa)
Methane	5	1520
Ethane	3	912
n-Butane	1.5	456
Propane	2.2	669
Ethylene	2.7	821

It is noted that, for some fuel gases, the threshold pressure P_s may not be defined as a function of the lower flammability limit of the fuel gas but as a function of the minimum concentration of oxidant enabling the flammability of the fuel gas. This is in particular the case when the minimum concentration of air enabling the flammability of the fuel gas is lower than the concentration of fuel gas corresponding to its lower explosive limit. In other words, in order to further reinforce the safety, it is advisable to make provision for a threshold pressure P_s which is also lower than the partial pressure of air, at atmospheric pressure, in a gas mixture comprising a concentration of air corresponding to a concentration of oxygen equal to the minimum concentration of oxygen enabling the flammability of the fuel gas.

It is furthermore noted that, in the embodiment represented, the inerting system also comprises a gas analyzer 15 for measuring a concentration of fuel gas in the gas phase. The gas analyzer 15 is here placed at the outlet of the pumping device 7. The gas analyzer 15 may in particular comprise a fuel gas detector selected from the group consisting of catalytic filament detectors, infrared detectors, in particular those operating by an absorbance and/or transmittance measurement, and electrochemical cell detectors. The gas analyzer 15 may be used during the first inerting mode in order to detect leaks of fuel gases, in addition to the comparison of

the pressure P of the gas phase inside the thermally insulating barrier 3 to a threshold pressure P_s . However, in order to enable the operation of the gas analyzer, the gas phase sample extracted from the thermally insulating barrier 3 must previously be diluted with an inert gas before its analysis. Furthermore, the gas
 5 analyzer 15 may also be used to analyze the gas phase of the thermally insulating barrier 3, at regular intervals, during the second inerting mode. In this case, it can also be envisioned to make provision for the control unit 10 to control the flow rates of injection of inert gas into the thermally insulating barrier 3 as a function of the concentrations of fuel gases measured.

10 It should be noted that, although the inerting process described above more particularly aims to carry out the inerting of the secondary thermally insulating barrier 3, the invention is not limited to such an embodiment. Indeed, according to other embodiments, the inerting process may also be implemented at the primary thermally insulating barrier 5 or be applied to a tank 1 comprising only a single
 15 thermally insulating barrier extending between an impermeable membrane intended to be in contact with the liquefied fuel gas and a load-bearing structure. Thus, generally, the inerting process may apply to any thermally insulating barrier positioned between two impermeable barriers and isolated from the ambient pressure by said impermeable barriers.

20 In addition, in one embodiment, an inerting process as described above is applied, independently, both within the secondary thermally insulating barrier 3 and within the primary thermally insulating barrier 5.

Hence, the inerting system also comprises:

- a pumping system that makes it possible to maintain the pressure of the gas phase
 25 contained in the primary thermally insulating barrier 5 around a setpoint pressure $P1'$;
- equipment for injecting inert gas and that makes it possible to flush the primary thermally insulating barrier 5 with an inert gas; and
- a pressure sensor that makes it possible to deliver a signal representative of the
 30 pressure of the gas phase inside the primary thermally insulating barrier 5.

As above, the control unit 10 compares the pressure of the gas phase inside the thermally insulating barrier 5 to a threshold pressure P_s' , greater than the setpoint pressure $P1'$, and automatically switches from the first inerting mode to the

second inerting mode of the primary thermally insulating barrier 5 when the pressure of the gas phase contained in the primary thermally insulating barrier 5 exceeds the threshold pressure P_s' .

It is noted that, according to one embodiment, it is possible to make provision for the threshold pressure P_s to be variable.

Indeed, while the pressure in the primary thermally insulating barrier 5 is maintained below the threshold pressure P_s' , it may be considered that the primary 6 and secondary 4 impermeable membranes correctly ensure the impermeability. Hence, a rise in pressure in the secondary thermally insulating barrier 3 can, in these cases, only be due to a loss of impermeability of the load-bearing structure 2 and the gas penetrating the secondary thermally insulating barrier 3 can only be air. Hence, while the first inerting mode of the primary thermally insulating barrier 5 is implemented, a first value defined solely as a function of the minimum concentration of oxidant that enables the flammability of the fuel gas may be assigned to the threshold pressure P_s . However, as soon as the control unit 10 detects a pressure of the gas phase of the primary thermally insulating barrier 5 that exceeds the threshold pressure P_s' , it is then advisable to assign a second value to the threshold pressure P_s , which value should also be defined as a function of the lower flammability limit of the fuel gas as seen above.

In the same way, provision may also be made for the threshold pressure P_s' , the exceedance of which is capable of triggering the second inerting mode of the primary thermally insulating barrier 5, to be variable as a function of the inerting mode implemented in the secondary thermally insulating barrier 3.

With reference to figure 3, a cutaway view of a methane tanker 70 shows an impermeable and insulated tank 71 of prismatic general shape mounted in the double hull 72 of the tank. In a manner known per se, loading/offloading pipes 73 positioned on the upper deck of the tanker may be connected, by means of appropriate connectors, to a maritime or port terminal in order to transpire an LNG cargo from or to the tank 71.

Figure 3 represents an example of a maritime terminal comprising a loading and offloading station 75, a submarine pipe 76 and an onshore facility 77. The loading and offloading station 75 is a stationary offshore facility comprising a mobile arm 74 and a tower 78 that supports the mobile arm 74. The mobile arm 74 bears a

bundle of insulated flexible hoses 79 that can be connected to the loading/offloading pipes 73. The steerable mobile arm 74 is compatible with all sizes of methane tankers. A connecting pipe, not represented, extends inside the tower 78. The loading and offloading station 75 enables the loading and offloading of the methane
5 tanker 70 from or to the onshore facility 77. The latter comprises liquefied gas storage tanks 80 and connection pipes 81 connected via the submarine pipe 76 to the loading or offloading station 75. The submarine pipe 76 enables the transfer of the liquefied gas between the loading or offloading station 75 and the onshore facility 77 over a large distance, for example 5 km, which enables the methane
10 tanker 70 to be kept at a great distance from the coast during the loading and offloading operations.

In order to generate the pressure necessary for the transfer of the liquefied gas, on-board pumps in the tanker 70 and/or pumps equipping the onshore facility 77 and/or pumps equipping the loading and offloading station 75 are employed.

15 Although the invention has been described in connection with several particular embodiments, it is quite obvious that it is in no way limited thereto and that it comprises all the technical equivalents of the means described and also the combinations thereof if these fall within the scope of the invention.

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

In the claims, any reference sign between parentheses should not be
25 interpreted as a limitation of the claim.

CLAIMS

1. A process for inerting a wall of an impermeable and thermally insulating tank (1) intended to contain a liquefied fuel gas, wherein the wall has a multilayer structure comprising two impermeable barriers (2, 4) and one thermally insulating barrier (3) positioned between the two impermeable barriers (2, 4), said thermally insulating barrier (3) comprising insulating solid materials and a gas phase, said process making provision for:
 - implementing a first inerting mode wherein a control device starts a pumping device in order to place the gas phase of the thermally insulating barrier (3) under a setpoint negative relative pressure P_1 lower than a threshold pressure P_s , said threshold pressure P_s being lower than a flammability limit pressure P_i of the fuel gas;
 - detecting, during the first inerting mode, whether the pressure of the gas phase of the thermally insulating barrier (3) exceeds said threshold pressure P_s ;
 - switching from the first inerting mode to a second inerting mode in response to the detection of a pressure of the gas phase of the thermally insulating barrier (3) that exceeds the threshold pressure P_s , the second inerting mode making provision for flushing the thermally insulating barrier (3) with an inert gas.
2. The process for inerting a wall as claimed in claim 1, wherein the threshold pressure P_s is lower than the partial pressure of said fuel gas, at atmospheric pressure, in a gas mixture comprising a concentration of the fuel gas corresponding to the lower explosive limit of said fuel gas in air, at 25°C.
3. The process for inerting a wall as claimed in claim 2, wherein the threshold pressure P_s is between 20% and 35% of the partial pressure of said fuel gas, at atmospheric pressure, in a gas mixture comprising a concentration of the fuel gas corresponding to the lower explosive limit of said fuel gas in air, at 25°C.
4. The process for inerting a wall as claimed in claim 2, wherein the threshold pressure P_s is 30% of the partial pressure of said fuel gas, at atmospheric pressure, in a gas mixture comprising a concentration of the fuel gas corresponding to the lower explosive limit of said fuel gas in air, at 25°C.
5. The process for inerting a wall as claimed in any one of claims 1 to 4, wherein the threshold pressure P_s is lower than the partial pressure of air, at atmospheric pressure, in a gas mixture comprising a concentration of air

corresponding to a concentration of oxygen equal to a minimum concentration of oxygen enabling the flammability of the fuel gas.

6. The process for inerting a wall as claimed in any one of claims 1 to 5, wherein, in the second inerting mode, the thermally insulating barrier (3) is flushed
5 with an inert gas, at atmospheric pressure.

7. The inerting process as claimed in any one of claims 1 to 6, wherein the fuel gas is selected from the group consisting of methane, ethane, n-butane, propane, ethylene and mixtures thereof.

8. The inerting process as claimed in any one of claims 1 to 7, wherein the
10 inert gas is selected from the group consisting of dinitrogen, helium, argon and mixtures thereof.

9. The process for inerting a wall as claimed in any one of claims 1 to 8, wherein one of the impermeable barriers consists of a load-bearing structure (2), the other impermeable barrier consists of a secondary metallic membrane (4), and the
15 thermally insulating barrier is a secondary thermally insulating barrier (3), the multilayer structure additionally comprising a primary metallic membrane (6) intended to be in contact with the fuel gas stored inside the tank (1) and a primary thermally insulating barrier (5) positioned between the primary metallic membrane (6) and the secondary metallic membrane (4), said primary thermally insulating
20 barrier (5) comprising insulating solid materials and a gas phase, the process additionally making provision for:

- implementing a first inerting mode of the primary thermally insulating barrier (5) wherein a control device starts a pumping device in order to place the gas phase of the primary thermally insulating barrier (5) under a setpoint negative relative
25 pressure $P1'$ lower than a threshold pressure Ps' , said threshold pressure Ps' being lower than the flammability limit pressure Pi of the fuel gas;
- detecting, during the first inerting mode of the primary thermally insulating barrier (5), whether the pressure of the gas phase in said primary thermally insulating barrier (5) exceeds said threshold pressure Ps' ;
- 30 - switching from the first inerting mode to a second inerting mode of the primary thermally insulating barrier (5) in response to the detection of a pressure of the gas phase of the primary thermally insulating barrier (5) that exceeds the threshold

pressure P_s' , the second inerting mode making provision for flushing the primary thermally insulating barrier (5) with an inert gas.

10. The inerting process as claimed in claim 9, wherein the threshold pressure P_s is variable and wherein a first value is assigned to the threshold pressure P_s while the first inerting mode of the primary thermally insulating barrier (5) is implemented and a second value is assigned to the threshold pressure P_s in response to the detection of a pressure of the gas phase of the primary thermally insulating barrier (5) that exceeds the threshold pressure P_s' .

11. A system for inerting a wall of an impermeable and thermally insulating tank (1) intended to contain a liquefied fuel gas, wherein the wall has a multilayer structure comprising two impermeable barriers (2, 4) and one thermally insulating barrier (3) positioned between the two impermeable barriers (2, 4), said thermally insulating barrier (3) comprising insulating solid materials and a gas phase, the inerting system comprising:

- 15 - a pumping device (7) arranged in order to place the gas phase of the thermally insulating barrier (3) under a negative relative pressure P_1 lower than a threshold pressure P_s , said threshold pressure P_s being lower than a flammability limit pressure P_i of the fuel gas;
- a pressure sensor (9) capable of providing a signal representative of the pressure of the gas phase inside the thermally insulating barrier (3);
- 20 - inert gas injection equipment (11) connected, on one side, to an inert gas storage reservoir (12) and/or to an inert gas generator, and, on the other side, to a supply pipe (14) for supplying inert gas to the inside of the thermally insulating barrier (3); and
- 25 - a control unit (10) capable of:
 - o detecting whether the pressure of the gas phase of the thermally insulating barrier (3) exceeds said threshold pressure P_s ; and of
 - o generating a signal for starting the inert gas injection equipment (11) in response to the detection of a pressure of the gas phase of the thermally insulating barrier (3) that exceeds the threshold pressure P_s .
- 30

12. The inerting system as claimed in claim 11, wherein the inert gas injection equipment (11) is connected to a dinitrogen generator.

13. The inerting system as claimed in claim 11 or 12, comprising a gas analyzer (15) for measuring a concentration of fuel gas in the gas phase.

14. An impermeable and thermally insulating tank (1) intended to contain a liquefied fuel gas, comprising a wall having a multilayer structure comprising two impermeable barriers (2, 4) and one thermally insulating barrier (3) positioned
5 between the two impermeable barriers (2, 4), said thermally insulating barrier (3) comprising insulating solid materials and a gas phase, and a system for inerting the wall as claimed in any one of claims 11 to 13.

15. The impermeable and thermally insulating tank (1) as claimed in claim 14,
10 wherein one of the impermeable barriers consists of a load-bearing structure (2) and the other impermeable barrier consists of a secondary metallic membrane (4), the multilayer structure additionally comprising a primary metallic membrane (6) intended to be in contact with the fuel gas stored inside the tank (1) and a thermally insulating barrier (5) positioned between the primary metallic membrane (6) and the
15 secondary metallic membrane (4).

16. A tanker comprising a tank (1) for storing liquefied gas as claimed in claim 14 or 15.

17. A process for loading or offloading a tanker (70) as claimed in claim 16,
wherein a fluid is conveyed through insulated pipes (73, 79, 76, 81) from or to a
20 floating or onshore storage facility (77) to or from the tank (71) of the tanker.

18. A fluid transfer system, the system comprising a tanker (70) as claimed in claim 16, insulated pipes (73, 79, 76, 81) arranged so as to connect the tank (71) installed in the hull of the tanker to a floating or onshore storage facility (77) and a pump in order to drive a fluid through the insulated pipes from or to the floating or
25 onshore storage facility to or from the tank of the tanker.