

Description

Title: System for treating gas contained within a tank for storing and/or transporting gas in the liquid state and the gaseous state, the system being fitted on a ship

The present invention relates to the field of ships, the propulsion engines of which are supplied with natural gas and which are also capable of containing and/or transporting liquefied natural gas.

Such ships thus conventionally comprise tanks which contain natural gas in the liquid state. Natural gas is liquid at temperatures below -160°C , at atmospheric pressure. These tanks are never perfectly thermally insulated which means that at least some of the natural gas boils off therein. Thus, these tanks contain both natural gas in liquid form and natural gas in gaseous form. This natural gas in gaseous form forms a blanket at the top of the tank and the pressure in this top of the tank needs to be controlled, so as not to damage the tank. As is known, at least some of the natural gas present in gaseous form in the tank is thus used to supply, amongst other things, the engines that propel the ship.

However, when the ship is stationary, the consumption of gaseous natural gas by these engines is zero, or near zero, the natural gas present in the gaseous state in the tank no longer being consumed by these engines. Reliquefaction systems that allow the boil-off natural gas present in the tank to condense are thus fitted to the ship, in order to return this gas to this tank in the liquid state.

The reliquefaction systems currently in use are very expensive and the present invention seeks to overcome this disadvantage by proposing a system for treating gas that

comprises fewer components than the current systems, thus making it possible to reduce the operating costs of such systems, while at the same time performing at least as well.

5 One subject matter of the present invention is thus a system for the treatment of gas contained in a tank for storing and/or transporting gas in the liquid state and in the gaseous state, the tank being fitted to a ship and the system comprising at least:

- 10 - a heat exchanger configured to perform an exchange of heat between gas withdrawn from the tank in the gaseous state and compressed gas coming from the tank,
- a compression member configured to compress the gas in the gaseous state coming from the heat exchanger,
- 15 - a gas consuming apparatus that consumes gas in the gaseous state and is configured to be supplied with the compressed gas,
- a first pipe connecting the compression member to the gas consuming apparatus that consumes gas in the
- 20 gaseous state,
- a second pipe connecting the first pipe to an inlet orifice of the heat exchanger,
- a third pipe connecting an outlet orifice of the heat exchanger to a bottom of the tank,
- 25 - a bubbling member connected to the third pipe and configured to distribute gas coming from the heat exchanger in the gaseous state into the bottom of the tank.

30 What is meant by the "bottom of the tank" is a portion of the tank which extends from a bottom wall of the tank and a plane parallel to this bottom wall and positioned, at most, at 20% of a total height of the tank, this total height being measured along a straight line perpendicular to the bottom

35 wall of the tank between two opposite ends of this tank, along this straight line. Advantageously, the plane parallel

to the bottom wall and which contributes to delimiting the "bottom of the tank" may be positioned at 10% of the total height of the tank. Alternatively, the bubbling member may be fixed to the bottom wall of the tank. It will be appreciated from the foregoing that the heat exchanger is configured to perform an exchange of heat between the boil-off gas withdrawn from the tank and the gas compressed by the compression member. In other words, this heat exchanger comprises at least a first pass of which an inlet orifice is connected to the tank and of which an outlet orifice is connected to the compression member, and at least a second pass of which an inlet orifice is connected to the compression member and of which an outlet orifice is connected to the tank. According to the invention, the bubbling member is more particularly configured to generate gas bubbles and to disperse these in the bottom of the tank. These gas bubbles are then in contact with the liquid gas present in the tank. The difference in temperature between these gas bubbles and the liquid gas present in the tank causes these gas bubbles to condense.

According to one feature of the present invention, the gas treatment system comprises an expansion means and a heat exchanger, the heat exchanger being equipped with at least a first pass supplied with gas withdrawn in the liquid state from the tank and with at least a second pass supplied with gas withdrawn in the liquid state from the tank, and the expansion means being arranged between the tank and the first pass of the heat exchanger.

In other words, it will be appreciated that the liquid gas supplied to the first pass experiences an expansion, which is to say a reduction in its pressure, before it reaches this first pass, whereas the liquid gas which is sent into the second pass of the heat exchanger reaches this second pass immediately after having left the tank, namely without

having experienced any change to its pressure or its temperature other than that associated with the pumping itself. In other words, it will be appreciated that this heat exchanger is configured to perform an exchange of heat between expanded liquid gas and non-expanded liquid gas. For example, the expanded liquid gas may be expanded to a pressure below atmospheric pressure. Advantageously, the difference in pressure, and therefore temperature, between the liquid gas circulating in the first pass and the liquid gas circulating in the second pass allows the liquid gas circulating in the first pass to boil off and allows the liquid gas circulating in the second pass to be cooled. For example, an outlet orifice of the second pass of the heat exchanger may be fluidically connected to the tank so that the liquid gas cooled by passing through the second pass of the heat exchanger can be returned to this tank. It will be appreciated that injecting liquid gas thus cooled contributes to maintaining a stable temperature in the tank, and thus to limiting the phenomenon whereby the liquid gas contained in the tank boils off.

According to the invention, the bubbling member may comprise, for example, at least one boom provided with orifices that generate gas bubbles. Advantageously, these orifices are distributed over an entire length of the boom, which is to say a longest dimension of the boom, so as to allow the gas bubbles generated to be distributed uniformly in the bottom of the tank.

According to one exemplary embodiment of the present invention, the orifices of the boom each have a cross section comprised between 0.0078 mm^2 and 315 mm^2 . Advantageously, such a cross section makes it possible to generate gas bubbles that are small enough to condense rapidly and thus mix rapidly with the liquid gas contained in the tank.

According to one feature of the present invention, at least one expansion member is arranged on the first pipe. In other words, it will be appreciated that the gas that leaves the compression member is expanded before it reaches the heat exchanger, thereby notably facilitating the exchange of heat that takes place in this heat exchanger. Alternatively, the natural gas may reach the heat exchanger without having been expanded, which is to say that the natural gas then reaches the bubbling member at a higher pressure than if it were to experience an expansion before reaching the heat exchanger.

According to the invention, the gas treatment system may comprise a compression device arranged in parallel with the compression member, the compression member being configured to compress a first part of the gas in the gaseous state coming from the heat exchanger and the compression device being configured to compress a second part of the gas in the gaseous state coming from the heat exchanger, the first part of the gas coming from the heat exchanger being distinct from the second part of the gas coming from the heat exchanger. Alternatively, the compression device may be used to mitigate against a potential failure of the compression member.

For example, the gas stored and/or transported in the tank is natural gas. Alternatively, the gas treatment system according to the invention may be used with other types of gas, such as gaseous hydrocarbons or hydrogen for example.

According to one exemplary embodiment of the present invention, the gas treatment system comprises at least one first gas consuming apparatus and at least one second gas consuming apparatus, the first gas consuming apparatus being configured to be supplied with compressed gas at a first pressure, the second gas consuming apparatus being configured to be supplied with compressed gas at a second

pressure and the first pressure being lower than the second pressure. For example, the first gas consuming apparatus is an electric generator of DFDE (Dual Fuel Diesel Electric) type, which is a gas consuming apparatus configured to provide electrical power to the ship and the second gas consuming apparatus may be an engine used for the propulsion of the ship, such as an ME-GI or X-DF engine.

The present invention also relates to a ship for transporting liquefied gas, comprising at least one tank for a cargo of liquefied gas, at least one gas consuming apparatus that consumes boil-off gas and at least one gas treatment system as explained hereabove.

The present invention additionally relates to a system for loading or off-loading a liquid gas which combines at least one onshore means and at least one liquid gas transport ship according to the invention.

The present invention further relates to a method comprising at least the steps of:

- withdrawing gas in the gaseous state from the tank,
- warming the gas withdrawn in the gaseous state from the tank by an exchange of heat performed in a heat exchanger with gas compressed by a compression member,
- compressing the warmed gas, using the compression member,
- supplying a first part of the warmed and compressed gas to at least one gas consuming apparatus that consumes boil-off gas
- cooling a second part of the warmed and compressed gas by an exchange of heat performed in the heat exchanger with the gas withdrawn in the gaseous state from the tank,
- distributing into a bottom of the tank the second part of the gas cooled by passing it through the heat

exchanger.

According to the invention, the step of distributing the second part of the cooled gas consists in bubbling this
5 second part of the cooled gas.

According to one feature of the present invention, a pressure at the inlet to the third pipe is higher than a pressure measured at the bottom of the tank.

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The gas treatment method according to the present invention may also comprise at least a step of supercooling the natural gas withdrawn in the liquid state from the tank and at least a step of storing the supercooled natural gas at the bottom
15 of the tank. According to the invention, the supercooling step is performed by an exchange of heat between natural gas withdrawn from the tank in the liquid state and kept at atmospheric pressure, and natural gas withdrawn from the tank in the liquid state and expanded to below atmospheric
20 pressure. In other words, it will be appreciated from the foregoing that the step of supercooling the natural gas withdrawn in the liquid state from the tank is performed in the abovementioned heat exchanger.

Advantageously, the step of supercooling the natural gas withdrawn in the liquid state from the tank, the step of storing the supercooled natural gas in the bottom of the tank and the step of distributing in the bottom of the tank the second part of the gas cooled by passing it through the
30 heat exchanger are performed, in that order, at least twice in succession. As mentioned previously, the steps of supercooling and of storing the supercooled liquid natural gas allow a lowering of the temperature of the natural gas present in the liquid state in the tank. The step of
35 distributing the second part of the cooled gas for its part has a tendency to increase the temperature of the natural

gas present in the liquid state in the tank. In other words, the steps of supercooling and of storing the supercooled natural gas can be used to maintain the temperature of the liquid natural gas contained in the tank so as to prevent too great a quantity of this liquefied natural gas from boiling off during the step of distributing the gas into the bottom of the tank, as excessive boil-off would lead to an increase in the quantity of gaseous natural gas present in the top of the tank and therefore to an increase in the pressure in this tank which could, ultimately, damage same. The steps of supercooling, storing and distributing the natural gas in the tank therefore contribute to the stability of the pressure in this tank.

The present invention finally relates to a method for loading or off-loading a liquid gas into or from a gas transport ship according to the invention.

Further features, details and advantages of the invention will become more clearly apparent from reading the following description, on the one hand, and, on the other hand, from an exemplary embodiment given by way of nonlimiting indication and with reference to the attached drawings in which:

[Fig. 1] schematically illustrates a gas treatment system according to the present invention;

[Fig. 2] schematically illustrates a first mode of operation of the gas treatment system illustrated in figure 1;

[Fig. 3] schematically illustrates a second mode of operation of the gas treatment system illustrated in figure 1;

[Fig. 4] schematically illustrates a third mode of operation

of the gas treatment system illustrated in figure 1;

[Fig. 5] is a schematic depiction with cutaway of a tank of a methane transporter ship and of a terminal for the loading and/or off-loading of/from this tank.

In the remainder of the description, the terms "upstream" and "downstream" mean according to a direction in which a gas in the liquid, gaseous or biphasic state circulates through the element concerned. In figures 2 to 4, solid line represents circuit pipes through which gas circulates in the liquid, gaseous or biphasic state, while dotted line depicts circuit pipes through which the gas does not circulate.

Figures 1 to 4 illustrate a system 100 for the treatment of a gas contained in the liquid state and in the gaseous state in a tank 200 and various modes of operation of this gas treatment system 100. In the description which follows, the space in the tank 200 that is occupied by the gas in the gaseous state is referred to as the "top of the tank 201". The system 100 according to the present invention, when stationary, which is to say when no gas, be it in the gaseous, liquid or biphasic state, circulates, will be described first of all, with reference to figure 1. Three distinct modes of operation of the gas treatment system 100 according to the invention will then be described with reference to figures 2 to 4, making a distinction between a first mode of operation referred to as "in equilibrium", a second mode of operation referred to as "forced boil-off" and a third mode of operation referred to as "reliquefaction". In the remainder of the description, the terms "gas treatment system 100" and "system 100" will be used without distinction.

The description which will follow gives one particular example of an application of the present invention in which the tank 200 contains natural gas. It must be appreciated

that this is merely an example of an application and that the gas treatment system 100 according to the invention can be used with other types of gas, such as gaseous hydrocarbons or hydrogen for example.

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Figure 1 first of all illustrates, schematically, the system 100 for the treatment of gas contained in the tank 200 according to the invention, when stationary. According to the invention, the system 100 comprises at least a heat
10 exchanger 110, at least a compression member 120, at least a gas consuming apparatus 130 and at least a bubbling member 140. According to an example illustrated here, the system 100 further comprises a compression device 121, a compression means 122, a heat exchanger 170 and another gas consuming
15 apparatus 131.

As depicted, at least a first pipe 101 is arranged between the compression member 120 and the gas consuming apparatus 130, at least a second pipe 102 is arranged between the first
20 pipe 101 and the heat exchanger 110, and at least a third pipe 103 is arranged between the heat exchanger 110 and a bottom of the tank, which is to say a portion of the tank extending from a bottom wall 202 of the tank 200 and a plane parallel to this bottom wall and positioned, at maximum, at
25 20% of the total height h of the tank, this total height h being measured along a straight line perpendicular to the bottom wall of the tank between two opposite ends of this tank, along this straight line. Advantageously, the plane parallel to the bottom wall of the tank that contributes to
30 delimiting the "bottom of the tank" may be positioned at 10% of the total height h of the tank. Alternatively, the bubbling member may be fixed to the bottom wall 202 of the tank.

35 It must also be pointed out that the heat exchanger 110 comprises at least a first pass 111 connected on the one

hand to the tank 200, and more particularly to the top of the tank 201 and, on the other hand, to the compression member 120, and at least a second pass 112 itself connected, on the one hand, to the compression member 120 and on the other hand to the tank 200. More particularly, an inlet orifice 113 of the first pass 111 is connected to the top of the tank 201 by a fourth pipe 104, an outlet orifice 114 of the first pass 111 is connected to the compression member 120 by a fifth pipe 105, an inlet orifice 115 of the second pass 112 is itself connected to the compression member 120 by the second pipe 102, and an outlet orifice 116 of this second pass 112 is connected to the bottom of the tank 200 by the third pipe 103. In other words, it will be appreciated that the first pass 111 of the heat exchanger 110 has, passing through it, natural gas in the gaseous state withdrawn from the tank 200, and more particularly from the top of the tank 201, and that the second pass 112 of this heat exchanger 110 has, passing through it, natural gas withdrawn from the tank 200, and more particularly from the top of the tank 201, which is then compressed by the compression member 120. In other words, the heat exchanger 110 is configured to perform an exchange of heat between gas withdrawn in the gaseous state from the top of the tank 201 and sent directly into the heat exchanger 110, and gas withdrawn in the gaseous state from the top of the tank 201 and at least partially compressed by the compression member 120. What is meant by "sent directly into the heat exchanger 110" is that the natural gas withdrawn in the gaseous state experiences no change in pressure or in temperature other than that associated with its being drawn up, before it reaches the heat exchanger 110, and more particularly the first pass 111 of this heat exchanger 110. It will also be noted that there is a valve 150 on the second pipe 102, namely between the first pipe 101 and the heat exchanger 110. Alternatively, the valve 150 could be sited downstream of the heat exchanger 110, which is to say arranged on the

third pipe 103. This valve 150 thus controls the supply of gaseous natural gas to the second pass 112 of the heat exchanger 110.

5 Moreover, the third pipe 103 is connected to the bubbling member 140 which extends in the bottom of the tank. This bubbling member 140 according to the example illustrated here comprises a boom 141 provided with orifices 142 configured to generate bubbles 143 of natural gas. For
10 example, each of these orifices 142 has a cross section of between 0.0078 mm^2 and 315 mm^2 . As will be described in far greater detail hereinbelow, notably with reference to the third mode of operation of the system 100 according to the invention, these bubbles 143 of natural gas are thus mixed
15 with the liquid natural gas present in the tank 200, which allows the gaseous natural gas of which these gas bubbles 143 are formed to condense and thus return to the liquid state.

20 The compression member 120 and the compression device 121 are both connected to the same elements of the system 100, which is to say that they are connected, by the fifth pipe 105, to the first pass 111 of the heat exchanger 110, on the one hand, to a first gas consuming apparatus 130 by the first
25 pipe 101 and to a second gas consuming apparatus 131 by a sixth pipe 106 on the other hand. More particularly, it will be noted that the gaseous natural gas compressed by the compression member 120 and the gaseous natural gas compressed by the compression device 121 may be mixed in a single pipe
30 which then divides to reach the first or second gas consuming apparatus 130, 131. For example, the first gas consuming apparatus 130 is an electric generator of the DFDE (Dual Fuel Diesel Electric) type, which is to say a gas consuming apparatus configured to supply electrical power to the ship
35 and the second gas consuming apparatus 131 may be an engine for the propulsion of the ship, such as an ME-GI or X-DF

engine. It must be appreciated that this is merely one exemplary embodiment of the present invention and that provision could be made for different gas consuming apparatuses to be installed without departing from the context of the present invention. Furthermore, the sixth pipe 106 is also fluidically connected to the second pipe 102. In other words, one part of the compressed natural gas intended to be supplied to the second gas consuming apparatus 131 may be diverted to supply the second pass 112 of the heat exchanger 110. In order to control this diverting of the compressed natural gas intended to supply the second gas consuming apparatus 131, a valve 151 is fitted between the sixth pipe 106 and the heat exchanger 110.

According to various application examples of the present invention, provision may be made for just the compression member 120 to operate, the compression device 121 then providing redundancy, which is to say that the compression device 121 is then able to take the place of the compression member 120 should the latter fail. Alternatively, provision could be made for the compression member 120 and the compression device 121 to be in operation simultaneously, which is to say for a first part of the natural gas coming from the heat exchanger 110 then to be compressed by the compression member and for a second part of the natural gas coming from the heat exchanger 110 for its part to be compressed by the compression device 121, the first part and the second part of the natural gas coming from the heat exchanger being distinct.

According to any one of these application examples, the natural gas reaches the compression member 120 and/or the compression device 121 in the gaseous state and at a pressure of around 1 bar and this natural gas leaves the compression member 120 and/or the compression device 121 in the gaseous state and at high pressure, which is to say a pressure of

between 1 bar and 400 bar, advantageously between 1 bar and 17 bar, and more advantageously still, between 6 bar and 17 bar. The level of compression at the outlet of this compression member 120 and/or of this compression device 121 is dictated according to the type of gas consuming apparatus that is to be supplied.

Furthermore, an expansion member 181 may be arranged on the first pipe 101 and more particularly between the compression member 120 and the second pipe 102 so as to expand the natural gas leaving the compression member 120 and/or the compression device 121 before this gas reaches the heat exchanger 110 in which, as will be described in far greater detail hereinbelow, the compressed natural gas gives up heat energy to the natural gas in gaseous form sent directly to this heat exchanger 110 from the top of the tank 201. It will also be noted that the sixth pipe 106 has no expansion member. In other words, when the valve 151 situated between the sixth pipe 106 and the heat exchanger 110 is opened to supply the second pass 112 of this heat exchanger 110, the natural gas with which this second pass 112 is supplied is at a pressure of between 1 bar and 400 bar, advantageously between 1 bar and 17 bar, and more advantageously still, between 6 bar and 17 bar. In other words, the opening of the valve 151 positioned between the sixth pipe 106 and the heat exchanger 110 allows the bubbling member 140 to be supplied with natural gas at high pressure. It will therefore be appreciated that the valve 150 arranged on the second pipe 102 and the valve 151 arranged between the sixth pipe 106 and the heat exchanger 110 are never open simultaneously.

The heat exchanger 170 for its part also comprises a first pass 171 and a second pass 172. As illustrated, the first pass 171 is connected on the one hand to a first pump 210 arranged in the bottom of the tank 200 and, on the other hand, to the compression means 122 and the second pass 172

is itself connected on the one hand to a second pump 220 arranged in the bottom of the tank 200 and, on the other hand, also to the tank 200 and, more exactly, to a part of the tank 200 in which the natural gas is stored in the liquid state. More particularly, an inlet orifice 173 of the first pass 171 is connected to the first pump 210, an outlet orifice 174 of the first pass 171 is connected to the compression means 122, an inlet orifice 175 of the second pass 172 is connected to the second pump 220 and an outlet orifice 176 of the second pass 172 is connected to the tank 200. What is meant here by "connected to the tank" is that a seventh pipe 107 is connected to the outlet orifice of the second pass 172 of the heat exchanger 170 and that this seventh pipe 107 opens into the tank 200. According to an exemplary embodiment which has not been illustrated here, the first pass and the second pass of the heat exchanger may both be supplied by the one same pump, a fork then being formed between this single pump and the inlet orifices of the first and second passes of the heat exchanger.

Furthermore, an expansion means 182 is arranged between the first pump 210 and the heat exchanger 170. In other words, the gas withdrawn in the liquid state from the tank 200 by the first pump 210 is expanded before it reaches the first pass 171 of the heat exchanger 170. What is meant by "expanded" is that the liquid natural gas experiences a reduction in its pressure. In other words, the natural gas withdrawn from the tank in the liquid state by the first pump 210 reaches the heat exchanger 170 at a pressure below atmospheric pressure. Note in contrast that the second pump 220 is configured to send the natural gas withdrawn in the liquid state from the tank 200 directly into the second pass 172 of the heat exchanger 170, which means to say that the natural gas withdrawn in the liquid state from the tank 200 does not experience any change in temperature or pressure other than that associated with the pumping itself before it

reaches the second pass 172 of the heat exchanger 170. The heat exchanger 170 is thus configured to perform an exchange of heat between gas withdrawn from the tank 200 in the liquid state and which has undergone an expansion, and gas withdrawn from the tank in the liquid state and which has not experienced any change in pressure. According to an unillustrated embodiment in which the first pass and the second pass of the heat exchanger are supplied via the same pump, the expansion means is positioned downstream of the fork, which is to say between the fork and the first pass of the heat exchanger. It will therefore be appreciated from the foregoing that the liquid natural gas that circulates in the first pass 171 is warmed up to the point of boiling-off whereas the liquid natural gas circulating in the second pass 172 is supercooled before being returned to the bottom of the tank 200.

As mentioned hereinabove, the liquid natural gas circulates in the first pass 171 of the heat exchanger 170 at a pressure below atmospheric pressure. Hence, in order to ensure that this liquid natural gas does flow, the compression means 122 positioned between this heat exchanger 170 and the compression member 120 is configured to return the natural gas leaving this heat exchanger 170 to a pressure close to atmospheric pressure. For example, this compression means 122 is configured to compress the natural gas from 0.35 bar to 1 bar. The natural gas thus compressed is then able to reach the compression member 120 and/or the compression device 121 in one or each of which it experiences a second compression.

The first mode of operation of the system 100 according to the invention will now be described with reference to figure 2. As previously mentioned, this first mode of operation is referred to as "in equilibrium". In other words, this first mode of operation corresponds to the perfect

scenario in which the quantity of boil-off natural gas present in the top of the tank 201 in the gaseous state is identical to the requirements of the gas consuming apparatus 130 and/or 131. As schematically illustrated, in this first mode of operation, the valves 150, 151 are closed and the first and second pumps 210, 220 are not running. In this first mode of operation, the natural gas is thus withdrawn in the gaseous state from the top of the tank 201 and then sent directly to the compression member 120 and/or the compression device 121 so that its pressure can be increased to supply the gas consuming apparatus 130 and/or 131.

Figure 3 illustrates a second mode of operation of the system 100 according to the invention, this second mode of operation being referred to as "forced boil-off". This second mode of operation is implemented when the quantity of gaseous natural gas present in the top of the tank 201 is below the requirements of the item/items of gas consuming apparatus. This second mode of operation advantageously allows gaseous natural gas to be generated from liquid natural gas so as to be able to supply this or these items of apparatus.

As depicted in figure 3, in this second mode of operation, the first pump 210 and the second pump 220 are both activated, whereas the valves 150, 151 arranged respectively on the second pipe 102 and between the sixth pipe 106 and the heat exchanger 110 are closed so that the compressed natural gas coming from the compression member 120 and/or from the compression device 121 is sent in its entirety to the item/items of gas consuming apparatus. In other words, in this second mode of operation, the second pass 112 of the heat exchanger 110 is not supplied and the natural gas withdrawn from the tank in the gaseous state is sent directly to the compression member 120 and/or the compression device 121.

The heat exchanger 170 for its part is supplied with natural gas withdrawn from the tank 200 in the liquid state. Thus, the first pump 210 draws up liquid natural gas from the tank 200, this liquid natural gas passes through the expansion means 182 in which it experiences a reduction in its pressure. For example, provision could be made for this expansion to allow the liquid natural gas to pass from atmospheric pressure, namely around 1 bar, to a pressure below atmospheric pressure, for example to a pressure of around 0.35 bar. Thus, the first pass 171 of the heat exchanger 170 is supplied with liquid natural gas at low pressure.

The second pump 220 also draws up liquid natural gas from the tank 200 to supply the second pass 172 of the heat exchanger 170 directly. The second pass 172 of the heat exchanger 170 is thus supplied with liquid natural gas at atmospheric pressure. As previously mentioned, an exchange of heat is then performed in the heat exchanger 170, between the low-pressure liquid natural gas circulating in the first pass 171 and the liquid natural gas at atmospheric pressure circulating in the second pass 172. This results in a boiling-off of the low-pressure liquid natural gas circulating in the first pass 171 and a supercooling of the liquid natural gas at atmospheric pressure circulating in the second pass 172. The supercooled liquid natural gas can then be returned to the bottom of tank 200, via the seventh pipe 107, whereas the boil-off natural gas leaves the first pass 171 in the gaseous state to reach the compression means 122 in which it experiences an increase in its pressure. As mentioned hereinabove, the compression means 122 is able to compress the gaseous natural gas from a pressure of around 0.35 bar to a pressure of around 1 bar. The gaseous natural gas thus leaves the compression means 122 at atmospheric pressure and reaches the compression member 120 and/or the compression device 121 in one and/or both of which its

pressure is still high so that this gaseous natural gas can be used as fuel for the item/items of gas consuming apparatus.

5 It will be appreciated from the foregoing that, in the second mode of operation of the system 100 according to the invention, the heat exchanger 170 advantageously on the one hand allows the gas consuming apparatus 130, 131 to be supplied with gas and on the other hand allows cold to be
10 stored in the bottom of the tank 200. As will be described in far greater detail hereinbelow, the storage of supercooled liquid natural gas in the tank 200 lowers the temperature of the liquid natural gas contained in the tank 200 so as to reduce the boil-off of this liquid natural gas contained in
15 the tank 200.

The third mode of operation, referred to as "reliquefaction", illustrated in figure 4, itself corresponds to a mode of operation of the system 100 in which
20 the quantity of natural gas present in the gaseous state in the top of the tank 201 exceeds the gas requirements of the gas consuming apparatus 130 and/or 131.

In this third mode of operation, natural gas is withdrawn in
25 the gaseous state from the top of the tank 201 to supply the heat exchanger 110 and, more particularly, the first pass 111 of this heat exchanger 110. In this heat exchanger 110, the natural gas in the gaseous state collects heat energy from the gaseous and compressed natural gas circulating in
30 the second pass 112, as described hereinabove. The natural gas thus leaves the heat exchanger 110 in the gaseous state and at a temperature higher than the temperature it had in the top of the tank 201. This warmed gaseous natural gas thus reaches the compression member 120 and/or the
35 compression device 121 in one or both of which it experiences an increase in its pressure to a value sufficient to supply

at least one of the items of gas consuming apparatus 130, 131. Thus, part of this warmed and compressed gaseous natural gas is supplied to the gas consuming apparatus 130 and/or 131. At least one of the valves 150, 151 is itself open to
5 allow another part of this warmed and compressed gaseous natural gas to reach the second pass 112 of the heat exchanger 110. It must be appreciated that the part of the warmed and compressed gaseous natural gas supplied to the gas consuming apparatus 130 and/or 131 is distinct from the
10 other part of this warmed and compressed gaseous natural gas that reaches the second pass 112 of the heat exchanger 110. As described hereinabove, the gaseous natural gas circulating in the second pass 112 of the heat exchanger 110 gives up heat energy to the gaseous natural gas circulating
15 in the first pass 111 of this heat exchanger 110 so that the gaseous natural gas leaves the heat exchanger 110 and reaches the third pipe 103 at a temperature lower than the temperature it had on entering the second pass 112. However, it must be appreciated that the natural gas leaves the second
20 pass 112 of the heat exchanger 110 in the gaseous state.

As previously mentioned, the third pipe 103 is connected to the bubbling member 140. The gaseous natural gas that leaves the second pass 112 of the heat exchanger 110 cooled thus
25 reaches this bubbling member 140 and passes through the orifices 142 formed in the boom 141 of this bubbling member 140 so that gas bubbles 143 are generated and released in the bottom of the tank 200. These gas bubbles 143 thus find themselves in contact with the liquid natural gas contained
30 in the tank 200, causing these gas bubbles to condense and therefore turn into liquid natural gas which then mixes with the rest of the liquid natural gas present in the tank 200.

Advantageously, the orifices 142 of the bubbling member 140
35 are uniformly distributed over an entire length of the boom 141, which is to say a longest dimension of this boom 141,

so that the gas bubbles 143 are distributed equally in the bottom of the tank 200, thus increasing the contact area and the temperature difference between each gas bubble and the liquid natural gas contained in the tank 200. It will be appreciated that the release of these gas bubbles 143 has a tendency to increase the temperature of the liquid natural gas contained in the tank 200.

According to the invention, the second mode of operation and the third mode of operation are advantageously implemented in succession. Specifically, as described with reference to figure 3, the second mode of operation allows cold to be stored in the bottom of the tank - thanks to the return to the bottom of this tank of the natural gas that has been supercooled by the exchange of heat performed in the heat exchanger 170. The temperature of the liquid natural gas contained in the tank 200 is thus lowered, and the rise in temperature of this liquid natural gas which is generated by the release of the gas bubbles 143 via the bubbling member 140 upon implementation of the third mode of operation is controlled. In other words, without the prior cold-storage step, the release of the gas bubbles 143 by the bubbling member 140 would lead to an excessive increase in the temperature of the liquid natural gas contained in the tank 200, which would result in boil-off of this liquid natural gas and therefore in an increase in pressure which could damage the tank 200. In other words, the second mode of operation allows cold to be stored in anticipation of an increase in the temperature of the liquid natural gas contained in the tank as a result of the release of the gas bubbles 143 by the bubbling member 140 when the system 100 switches to the third mode of operation.

It will be appreciated from the foregoing that, for optimal operation of the system 100, which is to say operation in which the pressure in the top of the tank 201 is controlled,

it is necessary to alternate between the second and third modes of operation of this system 100.

5 Finally, figure 5 is a cutaway view of a ship 70 showing the tank 200 which contains the natural gas in the liquid state and in the gaseous state, this tank 200 being of prismatic overall shape and mounted in a double hull 72 of the ship. The wall of the tank 200 comprises a primary sealing membrane intended to be in contact with the liquefied gas contained
10 in the tank, a secondary sealing membrane arranged between the primary sealing membrane and the double hull 72 of the ship, and two insulating barriers arranged respectively between the primary sealing membrane and the secondary sealing membrane and between the secondary sealing membrane
15 and the double hull 72.

Loading and/or off-loading pipelines 73 arranged on the upper deck of the ship may be coupled, by means of suitable connectors, to a maritime or harbor terminal to transfer the
20 cargo of natural gas in the liquid state from or to the tank 1.

Figure 5 also depicts an example of a maritime terminal comprising a loading and/or off-loading station 75, an
25 underwater pipe 76 and an on-shore installation 77. The loading and/or off-loading station 75 is a fixed off-shore installation comprising a mobile arm 74 and a tower 78 supporting the mobile arm 74. The mobile arm 74 supports a bundle of insulated pipelines 79 capable of being connected
30 to the loading and/or off-loading pipelines 73. The orientable mobile arm 74 can be adapted to all sizes of ship. The loading and off-loading station 75 allows the loading and/or off-loading of the ship 70 from or to the onshore installation 77. The latter comprises liquefied gas storage
35 tanks 80 and connecting pipes 81 connected by the underwater pipe 76 to the loading or off-loading station 75. The

underwater pipe 76 is used for transferring liquefied gas between the loading or off-loading station 75 and the on-shore installation 77 over a great distance, for example of 5 km, which allows the ship 70 to stand off a long way off shore during the loading and/or off-loading operations.

In order to generate the pressure needed for transferring the liquefied gas, use is made of the off-loading pump or pumps mentioned above and supported by the loading and/or off-loading tower belonging to the tank 200 and/or pumps with which the on-shore installation 77 is equipped and/or pumps with which the loading and off-loading station 75 is equipped.

Of course, the invention is not restricted to the examples which have just been described, and numerous modifications may be made to these examples without departing from the scope of the invention.

Thus, the present invention proposes a gas treatment system that allows the gas consuming apparatus present on a ship to be supplied with gas that has boiled off naturally, with forcibly boiled-off liquid gas, and also allows the naturally boiled-off gas to be condensed if there is too much of it compared with the energy demands of the gas consuming apparatus of the ship, advantageously for a limited cost.

The present invention would naturally not be restricted to the means and configurations described and illustrated here and also extends to any equivalent means and any equivalent configuration and to any technically workable combination of such means.

CLAIMS

1. A system (100) for the treatment of gas contained in a tank (200) for storing and/or transporting gas in the liquid state and in the gaseous state, the tank being fitted to a ship and the system (100) comprising at least:

- a heat exchanger (110) configured to perform an exchange of heat between gas withdrawn from the tank (200) in the gaseous state and compressed gas coming from the tank (200),
- a compression member (120) configured to compress the gas in the gaseous state coming from the heat exchanger (110),
- a gas consuming apparatus (130, 131) that consumes gas in the gaseous state and is configured to be supplied with the compressed gas,
- a first pipe (101) connecting the compression member (120) to the gas consuming apparatus (130, 131) that consumes gas in the gaseous state,
- a second pipe (102) connecting the first pipe (101) to an inlet orifice (115) of the heat exchanger (110),
- a third pipe (103) connecting an outlet orifice (116) of the heat exchanger (110) to a bottom of the tank (200),
- a bubbling member (140) connected to the third pipe (103) and configured to distribute gas coming from the heat exchanger (110) in the gaseous state into the bottom of the tank (200).

2. The system (100) for treating gas as claimed in the preceding claim, comprising an expansion means (182) and a heat exchanger (170), the heat exchanger (170) being equipped with at least a first pass (171) supplied with gas withdrawn in the liquid state from

the tank (200) and with at least a second pass (172) supplied with gas withdrawn in the liquid state from the tank (200), and the expansion means (182) being arranged between the tank (200) and the first pass (171) of the heat exchanger (170).

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3. The system (100) for treating gas as claimed in either one of the preceding claims, wherein the bubbling member (140) comprises at least one boom (141) provided with orifices (142) that generate gas bubbles (143).

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4. The system (100) for treating gas as claimed in the preceding claim, wherein the orifices (142) of the boom (141) each have a cross section comprised between 0.0078 mm^2 and 315 mm^2 .

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5. The system (100) for treating gas as claimed in any one of the preceding claims, wherein at least one expansion member (181) is arranged on the first pipe (101).

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6. The system (100) for treating gas as claimed in any one of the preceding claims, comprising a compression device (121) arranged in parallel with the compression member (120), the compression member (120) being configured to compress a first part of the gas in the gaseous state coming from the heat exchanger (110) and the compression device (121) being configured to compress a second part of the gas in the gaseous state coming from the heat exchanger (110), the first part of the gas coming from the heat exchanger (110) being distinct from the second part of the gas coming from the heat exchanger (110).

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7. The system (100) for treating gas as claimed in any one of the preceding claims, wherein the gas stored

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and/or transported in the tank (200) is natural gas.

- 5 8. The system (100) for treating gas as claimed in any one of the preceding claims, comprising at least one first gas consuming apparatus (130) and at least one second gas consuming apparatus (131), wherein the first gas consuming apparatus (130) is configured to be supplied with compressed gas at a first pressure, wherein the second gas consuming apparatus (131) is configured to be supplied with compressed gas at a second pressure and wherein the first pressure is lower than the second pressure.
- 10 9. A ship for transporting liquefied gas, comprising at least one tank (200) for a cargo of liquefied gas, at least one gas consuming apparatus (130, 131) that consumes boil-off gas and at least one gas treatment system (100) as claimed in any one of the preceding claims.
- 15 10. A system (100) for loading or off-loading a liquid gas which combines at least one onshore means and at least one liquid gas transport ship as claimed in the preceding claim.
- 20 11. A method for treating a gas contained in a tank (200) fitted to a ship, the method implementing a gas treatment system (100) as claimed in any one of claims 1 to 8, the method comprising at least the steps of:
- 25 30 - withdrawing gas in the gaseous state from the tank (200),
- warming the gas withdrawn in the gaseous state from the tank (200) by an exchange of heat performed in a heat exchanger (110) with gas compressed by a compression member (120),
- 35 - compressing the warmed gas, using the compression

member (120),

- supplying a first part of the warmed and compressed gas to at least one gas consuming apparatus (130, 131) that consumes boil-off gas
- cooling a second part of the warmed and compressed gas by an exchange of heat performed in the heat exchanger (110) with the gas withdrawn in the gaseous state from the tank (200),
- distributing into a bottom of the tank (200) the second part of the gas cooled by passing it through the heat exchanger (110).

12. The method for treating gas as claimed in the preceding claim, wherein the step of distributing the second part of the cooled gas consists in bubbling this second part of the cooled gas.

13. The method for treating gas as claimed in either one of claims 11 and 12, wherein a pressure at the inlet to the third pipe (103) is higher than a pressure measured at the bottom of the tank (200).

14. The method for treating gas as claimed in any one of claims 11 to 13, comprising at least a step of supercooling the natural gas withdrawn in the liquid state from the tank (200) and at least a step of storing the supercooled natural gas at the bottom of the tank (200).

15. The method for treating gas as claimed in the preceding claim, wherein the supercooling step is performed by an exchange of heat between natural gas withdrawn from the tank (200) in the liquid state and kept at atmospheric pressure, and natural gas withdrawn from the tank (200) in the liquid state and expanded to below atmospheric pressure.

16. The method for treating gas as claimed in either one of claims 14 and 15, wherein the step of supercooling the natural gas withdrawn in the liquid state from the tank (200), the step of storing the supercooled natural gas in the bottom of the tank (200) and the step of distributing in the bottom of the tank (200) the second part of the gas cooled by passing it through the heat exchanger (110) are performed, in that order, at least twice in succession.
17. A method for loading or off-loading a liquid gas into or from a gas transport ship as claimed in claim 9.