

DEVICE AND METHOD FOR SUPPLYING FUEL TO A POWER- GENERATING FACILITY

TECHNICAL FIELD

5 The invention concerns a device and a method for supplying fuel to a power-generating installation, in particular on board a ship.

PRIOR ART

 The prior art includes in particular the documents WO-A1-2012/089891 and WO-A1-2015/183966.

10 In order to transport gas, such as natural gas, more easily over long distances the gas is generally liquefied (to become liquefied natural gas - LNG) by cooling it to cryogenic temperatures, for example -163°C at atmospheric pressure. The liquefied gas is then loaded into specialized ships.

 In a ship for transporting liquefied gas, for example of the methane
15 tanker type, an energy producing installation is provided to meet the energy demands of operating the ship, in particular for propulsion of the ship and/or production of electricity for on board equipment.

 An installation of this kind routinely includes thermal machinery consuming gas from an evaporator that is fed from the liquefied gas cargo
20 transported in the tank or tanks of the ship.

 The document FR-A-2 837 783 provides for supplying an evaporator of this kind and/or other systems necessary for propulsion with the aid of a pump immersed at the bottom of a tank of the ship.

 A pump placed in this way has disadvantages. According to the IACS
25 (*International Association of Classification Societies*) code, it must be inspected regularly. Inspection of the pump may necessitate opening the main tank, which leads to immobilization of the ship and may damage the tank.

 A solution to this problem would be to provide an opening at the bottom of the tank and to evacuate the liquefied gas from the main tank from that
30 opening. However, the IGF and IGC (*International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk*) codes prohibit any

such opening in tanks of large volume, which is the case of the main tank of a ship.

The present invention proposes an improvement to the current state of the art and is simple, effective and economical.

5 STATEMENT OF THE INVENTION

The invention proposes a device for supplying fuel fluid to a power-generating installation, in particular on board a ship, including :

- a main liquefied gas tank,
- at least one first liquefied gas buffer tank,
- 10 - a first pipe for transferring fluid or liquefied gas from the first buffer tank to said installation, a first end of which opens into said first buffer tank and a second end of which is connected to said installation, in order to supply said installation with fuel fluid,
- a second pipe for transferring liquefied gas from the main tank to the first
- 15 buffer tank, said second pipe having a first end intended to be immersed in the liquefied gas contained in said main tank and a second end opening into said first buffer tank in order to feed said first buffer tank with liquefied gas, and
- means for reducing the pressure in said first buffer tank relative to said main tank, configured to aspirate fluid in said first buffer tank and to apply in said first
- 20 buffer tank an operating pressure less than the pressure in said main tank so that liquefied gas from said main tank is transferred by means of said second pipe and fed to said first buffer tank,
- characterized in that said pressure-reducing means include at least one compressor and in that said operating pressure is preferably below atmospheric
- 25 pressure.

The device according to the invention therefore addresses the problem of the prior art. Here a pump immersed in the main tank is not indispensable for routing liquefied gas from the main tank to the buffer tank. The pressure reduction in the buffer tank, that is to say the pressure difference between the

30 buffer tank and the main tank, is here such that it enables the buffer tank to be fed with liquefied gas contained in the main tank. The liquefied gas therefore circulates in the second pipe from the main tank to the buffer tank. BOG

contained in the main tank can conventionally be used to supply the installation of a ship. Here the device enables the addition to this source of BOG of additional fluid, in gas or liquid form, available in the buffer tank and can be routed by the first pipe to the installation.

5 The first buffer tank can have its pressure reduced to a pressure below atmospheric pressure (for example a pressure between -600 mbarg and -100 mbarg inclusive, or even between -600 mbarg and -200 mbarg inclusive). The compressor is able to produce a pressure reduction of this kind in order to transfer liquefied gas from the main tank to the buffer tank even if the latter is at
10 a pressure close to atmospheric pressure, for example between -100 mbarg and 100 mbarg inclusive or between -100 mbarg and 250 mbarg inclusive or between -100 mbarg and 400 mbarg inclusive.

 This enables immediate supply of gas to the installation including motors for example, whereas in contrast, according to the prior art, it is
15 necessary to wait for the pressure in the main tank to rise to a level sufficient to supply those motors. It will moreover be noted that in this case the pressure must be at levels compatible with the motors, for example 6 barg or more, and that the tank and in particular the type of tank may be chosen as a function of its pressure resistance.

20 The device according to the invention has one or more of the following features, separately from one another or in combination with one another:

- the main tank is of the membrane type, which is to say that its walls, in particular its inside walls, include at least one metal layer forming a sealed membrane and at least one thermal insulation layer;
- 25 - said main tank is configured to resist a pressure less than or equal to 3000 mbarg and preferably less than or equal to 750 mbarg;
- said main tank is of the type without a membrane;
- said main tank is configured to resist a pressure greater than or equal to 3000 mbarg and preferably greater than or equal to 6000 mbarg;
- 30 - said pressure-reducing means have an outlet intended to be connected to said installation;
- said pressure-reducing means include at least one compressor;

- a pump is connected to said first pipe and configured to aspirate liquefied gas from said first buffer tank;
- said compressor is connected to a third pipe for reducing the pressure in the first buffer tank a first end of which opens into said first buffer tank and a second
- 5 end of which is connected to an inlet of said compressor, said third pipe being configured to aspirate boil-off gas in said first buffer tank and to feed boil-off gas to said compressor;
- said compressor has an outlet connected to said installation in order to supply said installation with fuel gas;
- 10 - said second end of said third pipe is connected to said compressor by a first circuit of a heat exchanger;
- the device includes a fourth pipe for transferring gas from the main tank to the compressor;
- said fourth pipe has a first end opening into said main tank and a second end
- 15 connected to said compressor;
- said second end of said fourth pipe is connected with said second pipe to an inlet of said first circuit of the heat exchanger, an outlet of which is connected to said compressor;
- said first end of said second pipe has no pump;
- 20 - said first pipe includes at least a pump and/or a depressurization valve and/or a heat exchanger; that heat exchanger may be configured to drive evaporation of the liquefied gas circulating in said first pipe in order to supply said installation with fuel gas;
- said pump is configured to be controlled as a function of a fuel gas demand of
- 25 said installation;
- the device includes a fifth pipe for returning fluid from said pressure-reducing means to the main tank, a first end of which is connected to an outlet of said pressure-reducing means and a second end of which opens into said main tank;
- the device includes a second liquefied gas buffer tank:
- 30 - said second buffer tank is connected to:
 - said first pipe, which has a third end opening into said second buffer tank, and

- said second pipe, which has a third end opening into said second buffer tank;
- said second buffer tank is connected to said third pipe which has a third end opening into said second buffer tank;
- 5 - the device includes a fifth pipe for feeding gas to said first buffer tank and said second buffer tank, a first end of which is connected to an outlet of said pressure-reducing means, a second end of which opens into said first buffer tank, and a third end of which opens into said second buffer tank, said fifth pipe being configured to feed compressed gas to said first buffer tank and/or said
- 10 buffer tank;
- said first pipe is connected by a sixth pipe to a manifold for spraying liquefied gas in said main tank, said manifold being configured to spray liquefied gas in the form of droplets into the boil-off gas in said main tank in order to condense at least some of that boil-off gas;
- 15 - each of said tanks is equipped with a pressure sensor and/or a level sensor;
- the or each buffer tank is situated below an upper end of said main tank;
- the or each buffer tank is situated outside said main tank;
- the or each buffer tank may have an expansion and/or separation function; at least some of the liquefied gas feeding a buffer tank may undergo partial
- 20 evaporation and phase separation in the tank; less than half or less than 10% of the aspirated liquefied gas may be evaporated in this way; the gas, in liquid and gas form, outlets may be connected to said installation without passing or passing again through the main tank; a small proportion (1 to 10%) of the LNG taken off is evaporated upstream of the compressor, which enables use of a
- 25 reduced flow rate compressor; in fact (for a given gas LNG demand of the energy production installation) it is necessary to aspirate less than if only gas is aspirated (the volume of the gas is approximately 600 times greater than that of the liquid);
- said liquefied gas includes at least one pure body or gas, for example:
- 30
 - the first pipe transfers at least some of this pure gas (in liquid form) and where applicable mixed with another gas from the buffer tank to the installation, and/or

- said compressor aspirates at least some of this pure gas where applicable mixed with another gas; and/or
- said compressor supplies the installation with pure gas (where applicable mixed with another gas).

5 In the present application by “pure” is meant a single chemical species or body, as opposed to a mixture of bodies or species. A pure gas is for example a light gas or a heavy gas.

 In the present application there is meant by heavy gas and light gas, respectively, a heavy gas or a gas of high molar mass and a light gas or a gas
 10 of low molar mass. In liquefied gas the light gas is generally methane. In liquefied gas there may also be a small amount of nitrogen in the light fraction. The minority heavy fraction includes, for example, for the liquefied gas, propane, butane and ethane (which therefore evaporates at a higher temperature or at a lower pressure). In the liquefied gas the heavy gas
 15 represents between 5.2% and 49.8% of the total mass of liquefied gas. The heavy gas has for example a molar mass between 25 and 500% greater than those of the light gas.

 The present invention further concerns a ship, in particular for transporting liquefied gas, including at least one device as described
 20 hereinabove. The invention applies very particularly to a ship propelled by LNG (this is a special case of ships for transporting liquefied gas, if it is considered that a propulsion tank also has a transport function).

 The present invention further concerns a method for supplying with fuel an energy production installation, in particular on board a ship, by means of a
 25 device as described hereinabove characterized in that it includes:

- a step A of filling said first buffer tank by creating a reduced pressure in said first buffer tank relative to said main tank so that liquefied gas is transferred from the main tank to the first buffer tank.

 The method according to the invention may include one or more of the
 30 following steps or have one or more of the following features, separately from one another or in combination with one another:

- the method includes a step B1 of supplying said installation by means of said compressor by aspirating gas in said first buffer tank;
- during step B1 said installation is supplied by means of said compressor by taking up gas in said main tank and said first buffer tank;
- 5 - the method includes a step B2 of supplying said installation by means of said compressor by supplying with gas said first and/or second buffer tank in order to force liquefied gas to circulate in said first pipe;
- during step B1 or B2 said second buffer tank is fed with liquefied gas by creating by means of said compressor a reduced pressure in said second buffer tank relative to said main tank so that liquefied gas is transferred from the main tank to the second buffer tank;
- 10 - during step A, the pressure in said main tank is controlled by regulating the flow rate of gas circulating in said fourth pipe and/or in said fifth pipe;
- during step A or after step A, the pump of said first pipe is supplied with liquefied gas from said first buffer tank;
- 15 - the method includes a step B3 of supplying said installation via said first pipe by actuating said pump;
- during step A, the reduced pressure is maintained continuously for a predetermined time;
- 20 - the pressure is reduced by applying a pressure difference between said buffer tank and said main tank that is greater than a hydrostatic pressure generated by a substantially rectilinear and vertical height of said second pipe, where applicable with deduction of the head losses in that second pipe;
- said pump is controlled as a function of a fuel gas demand of said installation;
- 25 - at least some valves equipping one or more of said pipes are controlled as a function of a fuel gas demand of said installation;
- the pressure difference between the buffer tank and the main tank is increased in order to increase the flow rate at which liquefied gas is fed from the buffer tank as soon as the liquefied gas level in the buffer tank is below a particular threshold level;
- 30

- the pressure difference between one of the buffer tanks and the main tank is adjusted as a function of the rate of filling the other buffer tank with liquefied gas from said main tank;

- liquefied gas contained in said first buffer tank is routed by said first and sixth
5 pipes to said spray manifold.

BRIEF DESCRIPTION OF THE FIGURES

The invention will be better understood and other details, features and advantages of the present invention will become more clearly apparent on reading the following description given by way of nonlimiting example with
10 reference to the appended drawings, in which:

- figure 1 is a diagrammatic view of a device according to a first embodiment of the invention that here equips a ship,
- figures 2 to 6 are diagrammatic views corresponding to figure 1 and illustrating steps of a method according to the invention,
- 15 - figure 7 is a diagrammatic view of a device according to a second embodiment of the invention that here equips a ship,
- figures 8 to 12 are diagrammatic views corresponding to figure 7 and illustrating steps of a method according to the invention, and
- figure 13 is a diagrammatic view of a device according to a third embodiment
20 of the invention that here equips a ship.

DETAILED DESCRIPTION

In the following description the terms “upstream” and “downstream” refer to the flow of a fluid, such as a gas or a liquid, in a pipe or a circuit.

Figure 1 shows a device 10 according to a first embodiment of the
25 invention that may be considered as enabling the supply of fuel gas to a ship, such as a ship for transporting liquefied gas. The device 10 may therefore be used to supply with fuel gas an energy producing installation 12 on board the ship 14.

A ship 14 includes a tank 16 or a plurality of similar tanks 16 for storing
30 liquefied gas. The gas is for example methane or a mixture of gases including methane. The or each tank 16 may contain gas in liquefied form at a predetermined pressure and a predetermined temperature, for example at

atmospheric pressure and a temperature of the order of -163°C . One or more tanks 16 of the ship may be connected to the installation 12 by a device 10 according to the invention. The number of tanks is therefore not limiting on the invention. It is between and 1 and 6 inclusive for example. Each tank 16 may
 5 have a capacity between 1 000 (or even 100) and 50 000 m^3 .

Hereinafter the expression “the tank 16” must be interpreted as “the or each tank 16”.

The tank 16 contains liquefied gas 16aa and gas 16ab resulting from boiling off, in particular natural boiling off, of the liquefied gas 16aa in the tank
 10 16. The liquefied gas 16aa is naturally stored at the bottom of the tank 16 and the boil-off gas 16ab is situated above the liquefied gas level in the tank, diagrammatically represented by the letter N.

Hereinafter “LNG” designates liquefied gas, that is to say gas in liquid form, “BOG” designates boil-off gas, “NBOG” designates natural boil-off gas,
 15 and “FBOG” designates forced boil-off gas, these abbreviations being known to the person skilled in the art because they correspond to the first letters of the associated English-language expressions.

In the embodiment represented in figure 1 an end 22a of a pipe 22 is immersed in the LNG 16aa in the tank 16. There is preferably no pump at this
 20 end, to avoid maintenance thereof, and this end is preferably situated at the bottom of the tank in order to ensure that the pipe is supplied only with liquid LNG even if the tank is almost empty.

In the present application by tank “bottom” is meant a position situated less than one meter from a bottom wall of the tank, that bottom wall being in
 25 operation the wall of the tank closest to the center of the earth.

The pipe 22 includes a branch connection and has two ends situated outside the tank 16. One end 22d forms a port for filling the tank 16 with LNG and is therefore accessible by a user, in particular when loading LNG into the tank 16 of the ship.

30 The other end 22b of the pipe is connected to a buffer tank 18 also situated outside the tank 16. A valve 23d, 23b is associated with each of the ends 22d, 22b. The valve 23d enables blocking of the circulation of fluid in the

pipe 22 and therefore the supply of LNG to the tank 16. The valve 23d may also form a check valve. The valve 23b enables blocking of the supply of fluid to the buffer tank 18, in particular during bunkering of the main tank 16.

5 A manifold 52 for spraying droplets of LNG is situated in the top part of the tank 16, above the level N. The manifold 52 is therefore configured to spray droplets of LNG into the BOG in the tank. This enables forced recondensation of the BOG in the tank 16.

The tank 16 further includes a BOG inlet 16a and a BOG outlet 16b. The outlet 16b is connected to one end 30a of a pipe 30 that also includes a
10 branch connection defining two ends situated outside the tank 16. One end 30c forms a port for evacuating BOG from the tank 16, and is accessible by a user, in particular when loading LNG into the tank 16 of the ship.

The other end 30b of the pipe 30 is connected to an inlet 28aa of a first circuit 28a of a heat exchanger 28, an outlet 28ab of which is connected to an
15 inlet 20a of a compressor 20. The first circuit 28a is a cold circuit, the fluid circulating in that circuit 28a being intended to be heated by a fluid circulating in a second circuit 28b or hot circuit of the exchanger 28.

A valve 31a, 31c is associated with each end 30a, 30c. The valve 31a enables blocking of the circulation of fluid in the pipe 30 and therefore the
20 evacuation of BOG from the tank 16. The valve 31a may also form a check valve. The valve 31c enables blocking of the evacuation of BOG to the end 30c and the associated port.

The inlet 16a of the tank 16 is connected to one end 38b of a pipe 38 the other end 38a of which is connected to an outlet 20b of the compressor 20.
25 A valve 39 is associated with that pipe 38 and blocks the circulation of fluid from the outlet of the compressor 20 to the tank 16. The outlet 20b of the compressor 20 is moreover connected by a valve 41 to the installation 12.

The buffer tank 18 includes three ports, including an inlet 18a connected to the end 22b of the pipe 22 and two outlets 18b and 18c. The inlet 18a is
30 configured to receive LNG, the buffer tank 18 being intended to be supplied with LNG coming directly from the tank 16.

The outlet 18b is a gas and in particular BOG outlet and the outlet 18c is an LNG outlet. The outlet 18b is connected to one end 26a of a pipe 26 the opposite end 26b of which is connected to the inlet 20a of the compressor 20. In the example represented, the BOG leaving the buffer tank 18 is preheated by the exchanger 28 before feeding the compressor 20. To this end, the pipe 26 is connected to the pipe 30 upstream of the exchanger 28 and more particularly upstream of the circuit 28a so that the BOG coming both from the tank 16 and from the buffer tank 18 can feed the circuit 28a and be heated before feeding the compressor 20.

The pipe 26 includes a valve 27 able to block the circulation of fluid in the pipe 26 and in particular the evacuation of BOG from the buffer tank 18 to the exchanger 28.

The outlet 18c is connected to one end 32a of a pipe 32 that is connected to the installation 12 with the outlet 20b of the compressor 20. Here this pipe 32 includes or is connected to a pump 36 and is connected to a heat exchanger 34. The pipe 32 further includes two valves 33a, 33b, including for example a depressurization valve 33b. In the example represented, the pump 36, the valve 33b, the exchanger 34 and the valve 33a are disposed in the upstream to downstream direction, that is to say from the tank 18 to the outlet 20b of the compressor 20.

The pipe 32 is connected to the outlet 20b of the compressor 20 just upstream of the valve 41. Moreover, at the outlet of the valve 33a the pipe 32 is connected by a valve 33c to the pipe 38 just downstream of the valve 39.

In the example represented the LNG evacuated from the buffer tank 18 by the pump 36 is evaporated by the exchanger 34 before supplying the installation 12. To this end, the pipe 32 is connected to an inlet 34aa of a first circuit 34a of a heat exchanger 34 an outlet 34ab of which is connected to the valve 33a. The first circuit 34a is a cold circuit, the fluid circulating in that circuit 34a being intended to be heated by a fluid circulated in a second circuit or hot circuit 34b of the exchanger 34.

If the valve 33b were a depressurization valve and were to enable evaporation of all the LNG as FBOG, that FBOG would be heated by the

exchanger 34 before supplying the installation 12. The valve 33b is therefore advantageously configured so that the pressure of the FBOG at the outlet corresponds to the pressure at which the fuel gas is used in the installation 12.

A pipe 50 equipped with a valve 51 connects the spray manifold 52 to the pipe 32. Its upstream end is connected to the pipe 32 between the pump 36 and the valve 33b, that is to say just downstream of the pump 36, and its downstream end is connected to the manifold 52. It is therefore clear that LNG contained in the buffer tank 18 could feed the spray manifold 52, as mentioned above.

The buffer tank 18 is intended to be supplied with LNG from the tank 16. The operating pressure inside the buffer tank 18 is lower than the pressure at which the LNG is stored in the tank 16. Supplying the buffer tank 18 with LNG will therefore lead to partial evaporation of that LNG, reflected in the generation of FBOG in the buffer tank 18 and cooling of the remaining LNG in the buffer tank 18, referred to as "sub-cooled liquefied gas". The buffer tank 18 contains gas in liquefied form at a predetermined pressure and a predetermined temperature.

The buffer tank 18 therefore contains sub-cooled liquefied gas 18aa and gas 18ab resulting from boiling off, here forced boiling off, of the liquefied gas 16aa from the tank 16. The sub-cooled liquefied gas (LNGs) 18aa is naturally stored at the bottom of the buffer tank 18 while the boil-off gas (or FBOG) 18ab is situated above the liquefied gas level in the buffer tank 18, diagrammatically represented by the letter L.

Here the compressor 20 is used to apply the operating pressure inside the buffer tank 18. It is therefore configured to reduce the pressure in the buffer tank 18 relative to the tank 16. The pressure difference between them may be sufficient to force the circulation of LNG from the tank 16 to the buffer tank 18. In this latter case it is therefore clear that a submerged pump at the end 22a de the pipe 22 is not necessary. The conditions imposed on the buffer tank 18 by the compressor 20 are determined so as to generate LNGs in the buffer tank 18.

Alternatively or additionally, the pump 36 could be configured to participate in reducing the pressure in the buffer tank 18 relative to the main tank 16.

5 If the quantity of LNGs in the buffer tank 18 is too great and there is a risk of a threshold level being reached, LNGs may be transferred from the LNGs outlet of the buffer tank 18 to the installation 12 and/or the spray manifold 52 in the tank 16.

The LNGs provides cooling power that can be stored in the buffer tank 18 if it is not needed, for example during phases in which the quantity of NBOG produced is insufficient to meet the demand.

In the example represented, the reduced pressure in the tank 18 may allow the circulation of LNG in the pipe 22. The pipe 22 includes a vertical part forming a dip tube immersed in the LNG in the tank 16, its upper end being connected by a Tee to the rest of the pipe 22. The pressure difference between the two tanks 16, 18 should preferably be greater than the hydrostatic pressure generated by the height of the pipe 22 (to be more precise the height of the vertical part of the pipe 22 above the bottom of the tank up to the Tee (because, when the tank 16 is empty, it must be possible to raise the LNG to that height), less the head loss in the pipe 22. Alternatively, the pressure difference may be less if the tank 18 (and to be more precise the outlet 22b) is lower than that height and if the pipe 22 is primed (for example by a smaller pressure difference when the tank 16 is almost full).

The pressure difference may be regulated in the following manner:

- the gas demand of the installation 12 controls the pump 36 (the gas demand being determined for example by the difference between the setpoint of the installation 12 and the flow rate of gas measured between the outlet 32b and the installation 12),
- the tank 18 has a level sensor; as soon as the level in that tank 18 is below a lower threshold value the pressure difference is increased in order to increase the flow rate into the tank 18 (in the same way a higher threshold level may be provided, the pressure difference being reduced or cancelled out as soon as that level is reached).

A fuel gas supply device has two main functions:

- supplying fuel gas from the main tank 16 to the installation of the ship at a required flow rate (for example from 50 to 2000 kg/h), at a predetermined pressure (for example from 6 to 300 bars) and a predetermined temperature (for example 20°C); the fuel gas may be either in gas form (vapor) or liquid form;
- to adjust the pressure inside the main tank 16 within an acceptable range (for example between -100 and +700 mbarg or between -700 and 6000 mbarg).

The device 10 described is made up of a main tank 16 designed to contain cryogenic liquid for example at atmospheric pressure (for example with a volume of 1000 (or even 100) to 10 000 m³ and an authorized pressure from -100 to +700 mbarg or between -700 and 6000 mbarg) and the buffer tank 18 intended to contain cryogenic liquids (for example with a volume of 1 to 20 m³ and with a permitted pressure of -500 to 6000 mbarg). A pressure difference is created by the compressor 20 and/or the pump 36 between the main tank 16 and the buffer tank 18 (for example +500 mbarg in the main tank relative to the buffer tank) in order to be able to transfer liquid from the main tank 16 to the buffer tank 18. The liquid in the buffer tank 18 is compressed by the pump 36 and sent to the installation 12 via the evaporation valve 33b. The level of the liquid in the buffer tank 18 is controlled using appropriate instrumentation between for example 10% and 90% of the volume of the buffer tank. In this way the pump 36 is always supplied with 100% liquefied gas (a mixture of natural gas in the liquid and gas states would damage the pump). The way the device is controlled and the appropriate instrumentation are designed to maintain the pressure in the main tank 16 at the required level (for example between -100 and 700 mbarg). Each tank of the device 10 is therefore advantageously equipped with a pressure sensor and/or a level sensor.

Figures 2 to 6 illustrate phases of the operation of the device from figure 1 that may correspond to operating phases of the ship equipped with that device.

Here the supply method is described in three phases:

1. Minimal consumption: natural boil-off covers the energy demand of the installation (the propulsion engines of the ship are stopped or operate at a low load, the gas is mainly used to satisfy the requirements for electricity and heating).

5 2. Normal consumption: natural boil-off does not cover the energy demand of the ship.

3. No consumption (all the gas consuming elements on board the installation 12 are stopped with the exception of the gas compressor).

4. Filling.

10 1. Minimal consumption (cf. figure 2)

In the operating phase illustrated in figure 2 the main engine of the ship is stopped and the consumption of power is less than the maximum capacity of the compressor 20 ($< 2 \sim 3$ MW).

15 Evaporation of the LNG 16aa in the tank 16 leads to an increase in the pressure of the BOG 16ab in the tank 16. The BOG 16ab is aspirated by the compressor 20, heated in the exchanger 28 and the sent to the installation 12. This enables the pressure in the tank 16 to be maintained below a permissible threshold value.

To regulate the pressure in the tank 16 it is possible:

20 - to adjust the flow rate of BOG sent to the compressor 20 (if that flow rate is greater than the natural boil-off rate, the pressure in the tank 16 falls and if that flow rate is less than the natural boil-off rate the pressure in the tank rises);
 - to reinject some of the compressed gas (leaving the compressor 20) into the main tank 16 (for example if the specifications of the compressor 20 do not
 25 allow reduction of the input flow rate of the compressor below a certain value (which here is greater than the natural boil-off rate), some of the compressed gas is reinjected into the tank 16 via the pipe 38, to adjust the pressure in the tank 16.

30 The device 10 therefore supplies the requirements of the installation 12 for gas coming from the tank 16 and maintains the pressure inside that tank at the required level (for example between -100 and 700 mbarg).

2. Normal consumption

In the second phase of operation the consumption is normal.

The natural boil-off in the tank 16 is insufficient to meet the energy demand of the installation 12. Forced boil-off is necessary to meet the energy demand of the ship. This phase includes two steps:

- 5 - Preparing the forced boil-off: filling the buffer tank 18 and the pump 36 with liquefied natural gas.
- Forced evaporation: liquid from the buffer tank 18 is sent to the installation by forcing it to boil off.
- Preparing the forced evaporation (figure 3)

10 The first step consists in creating a pressure difference, for example of -500 mbar, between the main tank 16 and the buffer tank 18 by reducing the pressure in the buffer tank 18 and/or increasing the pressure in the tank 16. The pressure in the tank 16 may be increased as described hereinabove by reinjecting compressed BOG into it. The pressure in the buffer tank 18 may be
15 reduced by aspirating natural gas in the buffer tank by means of the compressor 20. With this pressure difference it is possible to aspirate the LNG contained in the tank 16 from a height of 10 m.

 If the pressure is increased in the tank 16, the BOG contained in the tank 16 tends to push the LNG out of the tank 16 and therefore to force its circulation
20 in the pipe 22 to the buffer tank 18. If the pressure decreases in the buffer tank 18 LNG is aspirated from the tank 16 to the buffer tank 18. The pressure difference contributes to the partial (flash) evaporation and the formation of BOG in the buffer tank 18. That BOG is aspirated by the compressor 20 so as to maintain the pressure difference between the tanks 16, 18.

25 The second step is to fill the pump 36 with liquefied natural gas. Once the buffer tank 18 has been filled with liquefied natural gas to the required level, for example to 90% of its volume, LNGs is fed by gravity to the pump 36. The pump 36 must be completely filled with liquid, as otherwise bubbles risk appearing and damaging the pump. The LNGs flows in the pipe 32 to the pump 36 and
30 passes through it, the pump 36 remaining closed.

 These operations may be combined with the first phase of operation to regulate the pressure in the main tank 16.

- Forced evaporation (figure 4)

The liquid is sent from the buffer tank 18 by forcing circulation of fluid to the installation 12.

LNGs from the buffer tank 18 is sent to the installation 12 via the
 5 exchanger 34. The flow rate of LNGs sent to the installation 12 is regulated by
 the pump 36. The installation 12 assigns priority to accepting gas from the
 compressor 20 (which manages the pressure in the tanks 16, 18), the top-up
 gas being obtained by the pump 36 that is used to cause LNG to circulate to the
 valve 33b for evaporation, preferably complete evaporation, of the LNG before it
 10 is heated in the exchanger 34. As described above, the buffer tank 18 is fed
 with LNG by reducing the pressure in the tank 18 relative to the tank 16. The
 exit of LNG from the buffer tank 18 is regulated by the pump 36. The LNG level
 in the buffer tank 18 is regulated to maintain it at the required level, for example
 between 10% and 90% of its volume.

15 These operations may be combined with the first phase of operation in
 order to regulate the pressure in the main tank 16.

3. No consumption (cf. figure 5)

This phase of operation is activated in an emergency. The installation 12
 is shut down, that is to say there is no consumption of fuel gas. The exchanger
 20 28, the compressor 20 and the pump 36 are operated by means of an
 emergency electrical generator.

For this phase, we will consider that the tanks 16, 18 contain LNG. The
 pump 36 causes LNG to circulate from the buffer tank 18 to the manifold 52. As
 there is a pressure difference between the tanks 16, 18, LNG continues to
 25 circulate from the tank 16 to the buffer tank 18 and boils off in the latter. This
 means that the LNG formed in the buffer tank 18 is sub-cooled compared to the
 LNG contained in the tank 16. The manifold 52 is supplied with sub-cooled
 liquefied gas from the buffer tank 18 and sprays droplets of that liquefied gas
 into the BOG in the tank 16. This enables the BOG in the tank 16 to be
 30 condensed and thus to participate in reducing and maintaining the pressure in
 the main tank 16.

The pressure in the tank 16 is therefore regulated by the flow of LNG coming from the buffer tank 18 and sprayed by the manifold 52. This phase of operation may be combined with the first or the second phase to reduce the pressure in the main tank 16.

5 4. Filling (cf. figure 6)

The valve 23d is open. LNG from a filling station is sent to the tank 16. The BOG that boils off during filling is evacuated by also opening the valves 31a and 31c so as to create a free flow of BOG to the station.

10 Figure 7 represents a device 110 in accordance with a variant embodiment of the invention which differs from the device 10 in particular in that it includes two buffer tanks 18 and 40.

The features described above with reference to the device 10 apply to the device 110 provided that they do not contradict what follows.

15 The pipe 22 is connected to each tank 18, 40 and has an end 22b connected to an LNG inlet 18a of the tank 18 and an end 22c connected to an LNG inlet 40a of the tank 40. A valve 23e, 23f is associated with each of those ends 23b, 23d in addition to the aforementioned valves 23b, 23d in the pipe 22.

Here each buffer tank 18, 40 includes four ports, two inlets 18a, 40a, 20 18d, 40d and two outlets 18b, 40b, 18c, 40c. The inlets 18a, 40a are respectively connected to the ends 22b, 22c of the pipe 22 and are configured to receive LNG, each buffer tank 18, 40 being intended to be fed with LNG coming directly from the tank 16.

The outlets 18b, 40b are gas and in particular BOG outlets and the 25 outlets 18c, 40c are LNG outlets. The outlets 18b, 40b are connected to respective ends 26a, 26c of the pipe 26 the opposite end 26b of which is connected to the inlet 20a of the compressor 20 or to the inlet 28aa of the circuit 28a of the exchanger 28, as mentioned above.

In addition to the valve 27, the pipe 26 includes a valve associated with 30 each of its ends 26a, 26b.

Another pipe 42 connects the outlet 20b of the compressor 20 to the inlets 18d, 40d of the tanks. These are compressed gas or BOG inlets, as the

tanks 18, 40 can be supplied with compressed BOG, as will be described in more detail hereinafter. The pipe 42 includes a valve 43 for blocking the circulation of fluid from the outlet of the compressor 20 to the tanks 18, 40. Moreover, each inlet 18d, 40d is associated with a valve enabling the tanks to
 5 be isolated from one another.

The outlets 18c, 40c of the tanks 18, 40 are connected to ends 32a, 32c of a pipe 32 that is connected to the outlet 20b of the compressor 20. Here that pipe 32 includes or is connected to a heat exchanger 34. The pipe further includes two valves 33a, 33b, one of which is for example a depressurization
 10 valve 33b. In the example represented, in the upstream to downstream direction, that is to say from the tanks 18, 40 to the outlet 20b of the compressor 20, are disposed the valve 33b, the exchanger 34 and the valve 33a. Valves are moreover associated with each of the outlets 18c, 40c.

The pipe 32 is connected to the outlet 20b of the compressor 20 just
 15 upstream of the valve 41. Moreover, at the outlet of the valve 33a the pipe 32 is connected by a valve 33c to the pipe 38, just downstream of the valve 39.

In the example represented the LNG evacuated from the buffer tank 18 is preheated by the exchanger 34 before it is supplied to the installation 12. To this end, the pipe 32 is connected to an inlet 34aa of a first circuit 34a of a heat
 20 exchanger 34 an outlet 34ab of which is connected to the valve 33a. The first circuit 34a is a cold circuit, the fluid circulating in that circuit 34a being intended to be heated by a fluid circulating in a second circuit 34b or hot circuit of the exchanger 34.

If the valve 33b were a depressurization valve and enabled evaporation
 25 of all of the LNG to form FBOG, that FBOG would be heated by the exchanger before being supplied to the installation 12. The valve 33b is therefore advantageously configured so that the pressure of the FBOG at the outlet corresponds to the pressure at which the fuel gas is used in the installation.

A pipe 50 connects the spray manifold 52 to the pipe 32. Its upstream
 30 end is connected to the pipe 32 upstream of the valve 33b and its downstream end is connected to the manifold 52. It is therefore clear that the LNG contained

in the buffer tanks 18, 40 could feed the spray manifold 52, as mentioned above.

In the example represented, the pressure reduction in the tank 18 must allow the circulation of LNG in the pipe 22. The pipe 22 has a vertical part forming a dip tube immersed in the LNG in the tank 16, its upper end being connected by an elbow to the rest of the pipe 22. The pressure difference between the two tanks 16, 18 must preferably be greater than the hydrostatic pressure generated by the height of the pipe 22 (to be more precise the height of the vertical part of the pipe 22 from the bottom of the tank to the elbow – because, when the tank 16 is empty, it must be possible to cause the LNG to rise to that height), less the head loss in the pipe 22. Alternatively, the pressure difference may be smaller if the tank 18 (and to be more precise the outlet 22b) is lower than that height and if the pipe 22 is primed (for example by a lower pressure difference when the tank 16 is almost full).

The pressure difference may be regulated in the following manner:

- the gas demand for the installation 12 controls the valves associated with the outlets 18c, 40c of the tanks 18, 40,
- the pressure difference is adjusted so as to fill the buffer tanks sufficiently quickly (this difference is therefore slaved to the gas demand for the installation 12).

Each tank 18, 40 functions like the tank 18 of the device 10. The tanks 18, 40 moreover has a supplementary function because of their connection to the outlet 20b of the compressor 20. The compressed BOG leaving the compressor 20 and feeding the tanks 18, 40 enables those tanks 18, 40 to be pressurized and to force the passage of the LNG 18aa, 40aa through their outlets 18c, 40c. It is therefore not necessary for these outlets to be equipped with a pump like that 36 of the device 10 to force the LNG to leave the buffer tanks 18, 40.

A fuel gas supply device has two main functions:

- to supply fuel gas from the main tank 14 to the installation 12 of the ship at a predetermined required flow rate (for example from 50 to 2000 kg/h), at a predetermined pressure (for example from 6 to 300 bar) and at a predetermined

temperature (for example 20°C). The fuel gas may be used either in gas (vapor) form or in liquid form;

- to adjust the pressure inside the main tank 16 within an acceptable range (for example between -100 and +700 mbarg).

5 The device 10 described is made up of the main tank 16 designed to contain cryogenic liquid for example at atmospheric pressure (for example with a volume of 1000 to 10 000 m³ and an authorized pressure of -100 to +700 mbarg) and the buffer tanks 18 intended to contain cryogenic liquids (for example with a volume of 1 to 20 m³ and with a permitted pressure from -500 to 10 6000 mbarg). The compressor 20 creates a pressure difference between the main tank 16 and the buffer tanks 18, 40 (for example +500 mbarg in the main tank relative to the buffer tank) in order to be able to transfer liquid from the main tank 16 to the buffer tanks 18, 40. The liquid in the buffer tanks 18, 40 is sent to the installation 12 via the boil-off valve 33b. The level of the liquid in 15 each buffer tank is controlled using appropriate instrumentation and is between for example 10% and 90% of the volume of the buffer tank.

 The way the device is controlled and the appropriate instrumentation are designed to maintain the pressure in the main tank 16 at the required level (for example between -100 and 700 mbarg). Each tank of the device 110 is 20 therefore advantageously equipped with a pressure sensor and/or a level sensor.

 Figures 8 to 12 illustrate operating phases of the device from figure 7 which may correspond to operating phases of the ship equipped with that device.

25 The liquefied gas cooling method is described here in four phases:

1. Minimum consumption: natural boil-off covers the energy demand of the installation 12 (the propulsion engines of the ship are stopped or operate at a low load, the gas is mainly used to satisfy the requirements for electricity and heating).
- 30 2. Normal consumption: natural boil-off does not cover the energy demand of the ship.

3. No consumption (all the gas consuming elements of the onboard installation 12 are stopped with the exception of the gas compressor).

4. Filling.

5 This is a sequential method in which the buffer tanks 18 and 40 are alternately filled and emptied. This description will concentrate only on the filling and the draining of the tank 18, the process for the tank 40 being symmetrical thereto.

1. Minimal consumption (cf. figure 8)

10 In the operating phase illustrated in figure 8 the main engine of the ship is stopped and the consumption of power is less than the maximum capacity of the compressor 20 ($< 2 \sim 3$ MW).

Evaporation of the LNG 16aa in the tank 16 leads to an increase in the pressure of the BOG 16ab in the tank 16. The BOG 16ab is aspirated by the compressor 20, heated in the exchanger 28 and the sent to the installation 12.
15 This enables the pressure in the tank 16 to be maintained below a permissible threshold value.

To regulate the pressure in the tank 16 it is possible:

- to adjust the flow rate of BOG sent to the compressor 20 (if that flow rate is greater than the natural boil-off rate, the pressure in the tank 16 falls and if that
20 flow rate is less than the natural boil-off rate the pressure in the tank rises);
- to reinject some of the compressed gas (leaving the compressor 20) into the main tank 16 (for example if the specifications of the compressor 20 do not allow reduction of the input flow rate of the compressor below a certain value (which here is greater than the natural boil-off rate), some of the compressed
25 gas is reinjected into the tank 16 via the pipe 38).

The device 10 therefore supplies the requirements of the installation 12 for gas coming from the tank 16 and maintains the pressure inside that tank at the required level (for example between -100 and 700 mbarg).

2. Normal consumption

30 In the second phase of operation the consumption is normal.

The natural boil-off in the tank 16 is insufficient to meet the energy demand of the installation 12. Forced boil-off is necessary to meet the energy demand of the ship. This phase includes two steps:

- Preparing the forced boil-off: filling the buffer tank 18 with liquefied natural gas from the tank 16.

- Forced evaporation: liquid from the buffer tank 18 is sent to the exchanger and then to the installation (whereas the other buffer tank 40 is filled with LNG).

- Preparing the forced evaporation (figure 9)

The first step consists in creating a pressure difference, for example -500 mbar between the main tank 16 and the buffer tank 18, by reducing the pressure in the buffer tank 18 and/or increasing the pressure in the tank 16. The pressure in the tank 16 may be increased as described for the first phase. The pressure in the buffer tank 18 may be reduced by aspirating natural gas into this tank by means of the compressor 20. With this pressure difference (-500 mbar) it is possible to aspirate LNG from the tank 16 from a height of approximately 10m.

If the pressure is increased in the tank 16, the BOG from the tank 16 forces the LNG to exit this tank and to circulate in the pipe 22 to the tank 18. If the pressure falls in the buffer tank 18, LNG contained in the tank 16 is aspirated into the tank 18. The pressure difference contributes to the partial boiling off of the LNG in the tank 18. The boil-off gas is aspirated by the compressor 20, which makes it possible to maintain a pressure difference between the tanks 16, 18. The tank 18 is filled with liquefied natural gas, for example up to 90% of its volume. These operations may be combined with the first phase of operation in order to regulate the pressure in the tank 16.

- Forced evaporation (figure 10)

The second step consists in pressurizing the tank 18 using the compressed natural gas at the outlet of the compressor 20.

The pipe 22 and the valve 23b used to fill the tank 18 with liquid and to aspirate the natural gas from this tank are closed. Compressed gas leaving the compressor 20 is sent (partly if necessary) to the tank 18 to pressurize it. This

enables forcing of the circulation of LNG from the tank 18 to the exchanger 34 and the installation 12.

While the tank 18 is supplying LNG to the installation 12 the tank 40 is filled with LNG from the tank 16 (only the valves 23d and 23e are therefore
5 closed, the valves 23b and 23f being open). The device 110 is advantageously designed to be able to fill the tank 40 at a rate higher than the rate of evacuation of the LNG from the tank 18 using the compressor 20.

The flow rate and the pressure of the LNG at the outlet of the buffer tank 18 are regulated by the valve 33b. The tank 18 is used until its LNG level is
10 too low (5% of the volume for example). At this moment the tank 40 is in turn ready to supply LNG to the installation 12. After this the tank 16 is filled with LNG, as described for the first step.

During this phase the tanks 18, 40 are therefore alternately filled with LNG and compressed using the compressor 20 to supply LNG to the installation
15 12.

These operations may be combined with the first phase of operation in order to regulate the pressure in the tank 16.

3. No consumption (cf. figure 11)

This phase of operation is activated in an emergency. The installation 12
20 is shut down, that is to say there is no consumption of fuel gas. The exchanger 28 and the compressor 20 are operated by means of an emergency electrical generator.

For this phase we consider that the tanks 16, 18 contain LNG. The compressor 20 is used to send compressed gas to the tank 18 and to increase
25 the pressure in that tank, which forces LNG to exit this tank and go to the manifold 52 in order to spray LNG into the BOG in the tank 16. This enables condensation of the BOG in the tank 16 and therefore participation in reducing and maintaining the pressure in the main tank 16.

The pressure in the tank 16 is therefore regulated by the flow rate of LNG
30 coming from the buffer tank 18 and sprayed by the manifold 52.

Once the tank 18 is empty this operation is repeated using the tank 40 while the tank 18 is refilled.

This phase of operation may be combined with the first or the second phase to reduce the pressure in the main tank 16.

4. Filling (cf. figure 12)

The valve 23d is open. LNG from a filling station is sent to the tank 16.

- 5 The BOG that boils off during filling is evacuated by also opening the valves 31a and 31c so as to create a free flow of BOG to the station.

Figure 13 represents a variant embodiment of the device 210 according to the invention that differs from the device 110 in particular in that it further includes a pump 36.

- 10 The features described above with reference to the device 110 apply to the device 210 provided that they do not contradict what follows.

- The pump 36 is situated on a pipe 54 an upstream end of which is connected to the outlets 18c, 40c of the tanks 18, 40 just downstream of their valves and the downstream end of which is connected to the pipe 32 just upstream of the valve 33b. That pipe 54 includes a valve 56 and extends in parallel with a portion of the pipe 32 that also includes an additional valve 58. This configuration offers the possibility of using or not using the pump 36 to evacuate the LNG contained in the tank 18, 40 to the spray manifold 525 and/or the installation 12.
- 15

- 20 The device therefore operates in a hybrid manner relative to the devices 10, 110.

CLAIMS

1. A device (10, 110, 210) for supplying fuel fluid to a power-
5 generating installation (12), on board a ship (14), including:
- a main liquefied fuel gas tank (16),
 - at least one first liquefied gas buffer tank (18),
 - a first pipe (32) for transferring liquefied gas from the first buffer tank (18) to
10 said installation (12), a first end (32a) of which opens into said first buffer tank
(18) and a second end (32b) of which is connected to said installation (12), in
order to supply said installation with fuel fluid,
 - a second pipe (22) for transferring liquefied gas from the main tank (16) to the
first buffer tank (18), said second pipe (22) having a first end (22a) intended to
be immersed in the liquefied gas (24) contained in said main tank (16) and a
15 second end (22b) opening into said first buffer tank (18) in order to feed said
first buffer tank with liquefied gas, and
 - means (20, 36) for reducing the pressure in said first buffer tank (18) relative
to said main tank (16), configured to aspirate fluid in said first buffer tank and to
apply in said first buffer tank an operating pressure less than the pressure in
20 said main tank so that liquefied gas from said main tank (16) is transferred by
means of said second pipe (22) and fed to said first buffer tank (18),
characterized in that said pressure-reducing means include at least one
compressor (20) and in that said operating pressure is below atmospheric
pressure.
- 25 2. The device (10, 110, 210) as claimed in the preceding claim, in
which said compressor (20) has an outlet (20b) connected to said installation
(12) in order to supply said installation (12) with fuel gas.
3. The device (10, 110, 210) as claimed in either one of the
preceding claims, in which to said first pipe (32) includes at least a pump (36)
30 and/or a depressurization valve (33a, 33b) and/or a heat exchanger (34) and is
configured to aspirate liquefied gas from said first buffer tank.
4. The device (10, 110, 210) as claimed in the preceding claim, in
which said compressor (20) is connected to a third pipe (26) for reducing the

pressure in said first buffer tank (18), a first end (26a) of which opens into said first buffer tank (18), and a second end (26b) of which is connected to an inlet (20a) of said compressor (20), said third pipe (26) being configured to aspirate boil-off gas (16ab) in said first buffer tank (18) and to feed said compressor (20) with boil-off gas (16ab).

5 5. The device (10, 110, 210) as claimed in the preceding claim, in which said second end (26b) of said third pipe (26) is connected to said compressor (20) by a first circuit (28a) of a heat exchanger (28).

10 6. The device (10, 110, 210) as claimed in any one of the preceding claims, in which the device includes a fourth pipe (30) for transferring gas from the main tank (16) to the compressor (20).

7. The device (10, 110, 210) as claimed in any one of the preceding claims, in which said first end (22a) of said second pipe (22) has no pump.

15 8. The device (10, 110, 210) according to claim 3, in which said pump (36) is configured to be controlled as a function of a fuel gas demand of said installation (12).

20 9. The device (10, 110, 210) as claimed in any one of the preceding claims, including a fifth pipe (38) for returning fluid from said pressure-reducing means (20, 36) to the main tank (16), a first end (38a) of which is connected to an outlet of said pressure-reducing means (20, 36) and a second end (38b) of which opens into said main tank (16).

10. The device (110, 210) as claimed in any one of the preceding claims, including a second liquefied gas buffer tank (40).

25 11. The device (10, 110, 210) as claimed in any one of the preceding claims, in which said first pipe (32) is connected by a sixth pipe (50) to a manifold (52) for spraying liquefied gas in said main tank (16), said manifold (52) being configured to spray liquefied gas in the form of droplets into the boil-off gas (16ab) in said main tank (16) in order to condense at least some of that boil-off gas (16ab).

30 12. A ship for transporting liquefied gas, including at least one device (10, 110) as claimed in any one of the preceding claims.

13. A method for supplying with fuel an energy production installation (12), on board a ship (14), by means of a device (10, 110) as claimed in any one of claims 1 to 11, characterized in that it includes:

- a step A of filling said first buffer tank (18) by creating a reduced pressure in said first buffer tank (18) relative to said main tank (16), so that liquefied gas is transferred from the main tank (16) to the first buffer tank (18).

14. The method as claimed in claim 13, including:

- a step B1 of supplying said installation (12) by means of said compressor (20), by aspirating gas in said first buffer tank (18).

15. The method as claimed in claim 13 or 14, the device (10) being moreover as defined in claim 10, including:

- a step B2 of supplying said installation (12) by means of said compressor (20) by supplying with gas said first and/or second buffer tank (18, 40) in order to force liquefied gas to circulate in said first pipe (32).

16. The method as claimed in any one of claims 13 to 15, in which, during step A or after step A, a pump (36) of said first pipe (32) is fed with liquefied gas from said first buffer tank (18).

17. The method as claimed in claim 16, including a step B3 of supplying said installation (12) via said first pipe (32) by actuating said pump (36).

18. The method as claimed in claim 15, in which the pressure difference between one of the buffer tanks (18, 40) and the main tank (16) is adjusted as a function of the rate of filling the other buffer (18, 40) tank with liquefied gas from said main tank (16).