

DESCRIPTION

Title of the invention: Determining operational energy losses in a liquefied gas transport ship

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The present invention relates to the field of liquefied gas transport ships, in particular methane tankers, and to the field of equipment for supervising energy consumption in these ships. More specifically, the invention relates to a method for determining data representative of operational energy losses in such a ship.

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Such a ship has a cargo hold accommodated to contain one or more tank(s) for transporting gas in the liquid state, these tanks having a capacity of several thousands and even several tens of thousands cubic meters. In the case of natural gas, the latter is kept in the tanks at about -163°C (degrees Celsius), at atmospheric pressure. Hence, the tanks are sealed and heat-insulated by a double insulation layer. However, since the liquefied natural gas (LNG) has a tendency to evaporate, for example because of a decrease in the pressure of the gas in the tanks or of a heat flow passing through the tank walls despite the double insulation, the upper portion of each tank, so-called tank headspace, is filled with gas in the vapor state. The latter is generally used as fuel for one or more engine(s) of the ship. The gas in the vapor state that is not used and cannot be kept in the tanks, is burnt via a flare and then discharged into the atmosphere, or more rarely discharged as such, or reliquefied by a (re)liquefaction system of the ship, so-called liquefaction system in this application, and returned at -163°C in the liquid state into the tanks. Hence, this liquefaction system allows saving gas, and therefore energy, which without this system would be lost, while consuming energy itself in order to operate.

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The energy balance of the operational losses of evaporated gas during a trip of the ship, also so-called operational BOR (standing for the "Boil-Off Rate") of a ship, is difficult to estimate. It depends in particular on the consumption of the engines of the ship which reduce the pressure in at least one of the tanks, the weather conditions (temperature, swell), the thermal resistance of the tanks, and the efficiency of the liquefaction system. Difficult weather conditions could be at the origin of large movements of the ship and therefore of the liquefied gas in the tanks, which generates an evaporation of the liquefied gas that is greater than when the ship navigates in calm water.

Yet, the ship-owners of such ships wish to know the exact performance of their ships in terms of operational energy losses, in particular for reasons related to contractual guarantees.

Currently, ship-owners use the decrease in the volume of the liquefied gas in the tanks to assess this operational performance, but this method is not accurate because of the variations of the movements of liquid in the tanks due to the movement of the ship itself. In addition, this decrease does not distinguish the energy losses due to the consumption of gas by the engines of the ship from the other losses.

Moreover, the operational performance that interests ship-owners should take account of the best conditions of use of the ship, and in particular of the liquefaction system of the ship. Yet, this liquefaction system, consuming energy itself, is not always activated over the trip of the ship, and therefore the operational performance measured by the method based on volume variation is often not representative of the operational performance enabled by the ship.

Predictive methods, using an estimated energy consumption of the ship over a trip as a function of different contexts of use, could provide operational performance taking account of the best conditions of use of the ship. However, these predictive methods turn out to be complex and in fine not very accurate, and result in poor assessment of the operational performance enabled by the ship, resulting in a lack of interest and trust in the data provided by these methods.

Hence, there is a need to provide an accurate operational performance of a liquefied gas transport ship equipped with a liquefaction system, so as to enable understanding of the operational performance differences as a function of the conditions of use of the ship.

The present invention aims to at least partially overcome the drawbacks of the prior art by providing a method for determining data representative of operational energy losses over a time interval, in a liquefied gas transport ship, corresponding determination device and system, as well as a computer program, which allow accurately comparing an active operational performance corresponding to a mode of use of the ship in which the liquefaction system is active, with a passive operational performance corresponding to a mode of use of the ship in which the liquefaction system is deactivated.

To this end, the invention provides a method for determining data representative of operational energy losses over a time interval, of a liquefied gas transport ship, this energy being initially stored in the form of liquefied gas and evaporated gas in at least one tank of the ship, the ship being equipped with a system for liquefying the evaporated gas, the determination method comprising steps of:

- calculating a first piece of data representative of an amount of energy consumed over the time interval, as a function of at least one measurement relating to the activity of at least one energy consumer of the ship,

- calculating a second piece of data representative of an energy variation of the liquefied gas present in the tank, as a function of a temperature variation of the liquefied gas in the tank over the time interval,

- adding the second piece of data to the first piece of data resulting in a piece of data representative of an actual operational energy loss in the ship,

the determination method being characterized in that it further comprises, when the liquefaction system is activated over the time interval:

- a step of calculating a third piece of data representative of an amount of energy saved by the liquefaction system over the time interval, and

- a step of adding the third piece of data to the piece of data representative of an actual operational energy loss, resulting in a piece of data representative of an estimated operational energy loss that would have been observed without the activation of the liquefaction system.

In this determination method according to the invention, the first piece of data is a function of one or more measurement(s) each related to one or more consumer(s) of the ship, for example several motors, so as to calculate all of the energy consumed by the consumers of the ship. The measurements are provided by one or more sensor(s), for example a flowmeter in a supply pipe of an engine of the ship.

In addition, in the case where the ship comprises several tanks, the second piece of data corresponds to an energy variation related to a temperature variation of the liquefied gas on all tanks, which could be positive or negative. Indeed, when the ship consumes a lot of evaporated gas, the pressure of the liquefied gas is likely to decrease, making the temperature of the LNG drop. In this case, the LNG has provided energy, which corresponds to a negative second piece of data. On the

contrary, when little evaporated gas is consumed, the pressure of the liquefied gas might increase and therefore make the temperature of the liquefied gas rise, resulting in an absorption of energy by the LNG, which corresponds to a positive second piece of data. Finally, the third piece of data corresponds to the energy saved on all tanks by the liquefaction system.

For example, the time interval for which the first, second and third data are calculated corresponds to one day, or one hour, this interval could be adapted according to the shortest time interval over which the liquefaction system is activated or deactivated. Indeed, it should be noted that the calculations of the third piece of data and of the estimated operational energy loss may also be performed when the liquefaction system is deactivated, simply the third piece of data will have the zero value and the estimated operational energy loss will be equal to the actual operational energy loss.

Thanks to the determination method according to the invention, the data representative of the operational energy losses is more accurate than in the prior art. In particular, the calculation of the first piece of data representative of the energy consumed by consumers of the ship uses measurements the integration of which over the time interval allows determining an actual mass of gas that has escaped from the tank, in contrast with a mass loss estimation of the prior art, calculated thanks to a volume variation, this estimation being quite inaccurate because of the movements of liquid which bias the volume and density data estimated mathematically.

In addition, the determination method allows comparing an actual operational energy loss corresponding to an active operational performance and to a mode of use where the liquefaction system is activated, to an estimated operational energy loss corresponding to a passive operational performance and to a mode of use where the liquefaction system is deactivated. This comparison is based on the amount of energy saved by the liquefaction system, whose value is not estimated but calculated accurately based on a measured mass, and is therefore very accurate. Thus, the passive operational performance is estimated in a quite reliable manner, which incites a user of the determination method according to the invention, to assess the operational performance actually enabled by the ship, and to activate the liquefaction system more frequently and therefore save energy over the trip of the ship. This approach differs from the prior art wherein the operational performance,

under conditions of use that are not met, is predicted based on energy savings or energy losses that are estimated, and therefore much less reliable. In particular, the estimations of volume losses based on liquid heights in the tanks of the ship are very unreliable, in particular because of the movements of the ship.

5 In one embodiment, the ship being equipped with a device for vaporizing the liquefied gas, the method for determining data representative of operational energy losses further comprises a step of calculating a fifth piece of data representative of an amount of energy of the liquefied gas pumped from the tank and intended to pass through the vaporization device over the time interval and a step of subtracting the
10 fifth piece of data from the piece of data representative of the actual operational energy loss.

 In another embodiment, the method for determining data representative of operational energy losses further comprises a step of calculating a sixth piece of data representative of an energy variation of the gas phase of the liquefied gas present in
15 the tank, as a function of a pressure and temperature variation in the tank over the time interval, and a step of adding the sixth piece of data to the piece of data representative of the actual operational energy loss.

 In one embodiment of the invention, each of the first, second, third, fifth and sixth data as well as the piece of data representative of an actual operational energy
20 loss and the piece of data representative of an estimated operational energy loss corresponds to a ratio between, on the one hand, an amount of energy lost over the time interval and, on the other hand, a reference amount of energy selected from among:

- an amount of energy calculated at the beginning of a period of use of the
25 determination method, or
- an amount of energy loaded in the ship.

 The amount of energy loaded in the ship corresponds to an energy contained in the tank(s) of the ship immediately after filling thereof. Of course, other reference amounts of energy can be used, for example the selected reference amount of
30 energy is the amount of energy that the liquefied gas loaded in the ship would represent if the latter has been loaded at a predetermined percentage of its total load capacity, for example 100%, 95%, or 90%.

 The use of this ratio enables a user of the determination method according to the invention to better perceive the operational energy losses over the time interval.

Preferably, the determination method according to the invention comprises an additional step of rendering the first, second and third data as well as the piece of data representative of an actual operational energy loss and the piece of data representative of an estimated operational energy loss, on a human-machine interface. For example, such a rendering consists of a display on a screen of said interface.

The invention also relates to a method for supervising operational data related to at least one tank of a liquefied gas transport ship, characterized in that it implements the method for determining data representative of operational energy losses according to the invention, and in that it comprises a step of calculating a fourth piece of data representative of a volume variation of the liquefied gas in the tank over the time interval.

This last calculation enables a user of the supervision method according to the invention, to compare the estimation provided by the prior art, to the estimated operational energy loss according to the invention. It shows the variability of this estimation of the prior art in comparison with the piece of data representative of the estimated operational energy loss.

The invention also relates to a device for determining data representative of operational energy losses, comprising means for implementing the determination method according to the invention. The determination device implements the determination method according to the invention in a hardware and/or software manner. It is adapted to recover measurement data from sensors allowing it to implement the different steps of the determination method according to the invention. Hence, it consists, for example, of an on-board computer of the ship, or a computer connected to the latter, or a remote server adapted to receive these data.

The invention also relates to a system for determining data representative of operational energy losses over a time interval, of a liquefied gas transport ship, this energy being initially stored in the form of liquefied gas and evaporated gas in at least one tank of the ship, the ship being equipped with a system for liquefying the evaporated gas, the determination system comprising:

- first means for calculating a first piece of data representative of an amount of energy consumed over the time interval, as a function of at least one measurement relating to the activity of at least one energy consumer of the ship,

- second means for calculating a second piece of data representative of an energy variation of the liquefied gas present in the tank, as a function of a temperature variation of the liquefied gas in the tank over the time interval,

- means for adding the second piece of data to the first piece of data, resulting in a piece of data representative of an actual operational energy loss in the ship, the determination system being characterized in that it further comprises:

- third means for calculating a third piece of data representative of an amount of energy saved by the liquefaction system over the time interval, when the liquefaction system is activated over the time interval, and

- means for adding the third piece of data to the piece of data representative of an actual operational energy loss, resulting, when the liquefaction system is activated over the time interval, in a piece of data representative of an estimated operational energy loss that would have been observed without the activation of the liquefaction system.

The determination system according to the invention is implemented in a hardware and/or software manner. The means of the determination system according to the invention enable the latter to implement the determination method according to the invention. Hence, the determination system according to the invention is for example identical to the determination device according to the invention, or comprises several remote physical entities, for example it is formed by the on-board computer of the ship and by a remote server adapted to receive data from the on-board computer of the ship, and possibly from a terminal connected to this remote server. The remote server is possibly formed by several computers connected together by one or more communication network(s). In another example, the determination system according to the invention comprises only the on-board computer and a terminal connected to this on-board computer. The determination system according to the invention may further comprise sensors such as temperature sensors for measuring the temperature of the liquefied gas or flowmeters allowing measuring a gas consumption of one or more consumer(s) of the ship.

In one embodiment of the invention, the ship being equipped with a device for vaporizing the liquefied gas, the determination system further comprises fifth means for calculating a fifth piece of data representative of an amount of energy of the liquefied gas pumped from the tank and intended to pass through the vaporization

device over the time interval and additional means for subtracting the fifth piece of data from the piece of data representative of the actual operational energy loss.

In another embodiment of the invention, the determination system may further comprise sixth means for calculating a sixth piece of data representative of an energy variation of the gas phase of the liquefied gas present in the tank, as a function of a pressure and temperature variation in the tank over the time interval, and additional means for adding the sixth piece of data to the piece data representative of the actual operational energy loss.

According to a preferred feature of the determination system according to the invention, the latter comprises a human-machine interface comprising display means adapted to provide a representation of the first, second, third, fifth and sixth data, as well as data representative of the actual and estimated operational energy losses, wherein the piece of data representative of an actual operational energy loss is visualized as a sum between at least two among the first, second, fifth and sixth data and, when the liquefaction system is activated over the time interval, the piece of data representative of an estimated operational energy loss is visualized in the form of a cumulation of the third piece of data and of the piece of data representative of the actual operational energy loss. In other words, this human-machine interface is adapted to implement the additional step of rendering the determination method according to the invention, in visual form.

In one embodiment of the invention, said representation is a waterfall chart. Such a chart is well suited to render in an immediately understandable fashion the mathematical relationships between the data rendered. Of course, in one variant, other graphical means such as tables of values, conventional histograms or pie charts can be used.

In this embodiment of the invention, the display means are adapted to represent the piece of data representative of the actual operational energy loss at a first location of the waterfall chart when the liquefaction system is activated over the time interval, or at a second location of the waterfall chart, distinct from the first location, when the liquefaction system is deactivated over the time interval, the piece of data representative of an estimated operational energy loss being shown by the display means at the second location when the liquefaction system is activated over the time interval.

This embodiment allows always reserving the first location on the graph to the active operational performance, and the second location to the passive operational performance. In other words, this enables a user of the determination system according to the invention to easily correlate the actual operational energy losses to a context of activation of the liquefaction system or to a context of deactivation of the liquefaction system.

In this embodiment, the rendering of the data is related to a time interval or to an average over time intervals. In particular, in this embodiment, the human-machine interface of the determination system according to the invention further comprises means for selecting at least one portion of a trip made by the ship, and means for selecting first time intervals during which the liquefaction system has been activated over this trip portion, the display means being adapted to represent when the first time intervals are selected by a user of the determination system:

- an average of each piece of data among the first, second, fifth and sixth data delivered by the means for calculating said piece of data for each of the first time intervals,

- an average of data representative of actual operational energy losses delivered by the addition means for each of the first time intervals,

- an average of third data delivered by the third calculation means for each of the first time intervals, and

- an average of data representative of estimated energy operational losses delivered by the addition means for each of the first time intervals.

In this embodiment of the invention, the human-machine interface of the determination system according to the invention further comprises means for selecting second time intervals during which the liquefaction system has been deactivated over this trip portion, the display means being adapted to represent when the second time intervals are selected by a user of the determination system:

- an average of each piece of data among the first, second, fifth and sixth data delivered by the means for calculating said piece of data for each of the second time intervals, and

- an average of data representative of actual operational energy losses delivered by the addition means for each of the second time intervals. For example, the means for selecting the first or second intervals are graphical buttons or tabs on the graphical interface rendered by the display means.

Complementary supervision data are rendered in this embodiment, enabling a user of the determination system according to the invention to correlate more data in order to better perceive the evolution of the operational energy losses rendered by the human-machine interface. Thus, in this embodiment, the human-machine interface further comprises means for selecting at least one tab related to an operational piece of data relating to the liquefied, evaporated, reliquefied or consumed gas in the tanks, adapted to make the display means display a graph of values corresponding to the selected tab, the values being those of the operational piece of data over one or more time interval(s) and being recorded in a memory of the determination system. For example, the operational piece of data is selected from among:

- a flow rate of evaporated gas sent to the liquefaction system over time,
- a cumulative mass of gas lost over time,
- a mass of non-cumulative gas lost over time,
- a density of the liquefied gas in the tank over time,
- a temperature of the liquefied gas in the tank over time,
- a pressure of the gas evaporated in the tank over time,
- a volume of the liquefied gas over time,
- a speed of the ship over time.

These data may be instantaneous or related to a predefined time interval.

The invention also relates to a system for supervising operational data related to at least one tank of a liquefied gas transport ship, characterized in that it comprises the system for determining data representative of operational energy losses according to the invention, and in that it comprises means for calculating a fourth piece of data representative of a volume variation of the liquefied gas in the tank over the time interval. Preferably, the display means of the determination system according to the invention are identical to display means of the supervision system according to the invention, and therefore also render the fourth piece of data representative of an energy loss in the tank over the considered time interval.

Finally, the invention relates to a computer program comprising program code instructions for executing the steps of the determination method according to the invention, when said program is executed on one or more processor(s).

The computer program is executed on one single processor, for example when it is executed in the determination device according to the invention, equipped

with this processor. It is executed on several processors, for example in the determination system according to the invention when the latter comprises several remote physical entities each equipped with one of these processors, in particular the calculation steps of the determination method according to the invention are implemented for example in a remote server or in the on-board computer of the ship, and the rendering step is implemented in a terminal connected to the remote server or to the on-board computer.

It should also be noted that the determination method according to the invention is implemented dynamically during the trip of the ship, or statically once the ship has arrived at its destination. In the case where the calculation steps of the determination method according to the invention are implemented in a remote server of the determination system according to the invention, the remote server therefore comprises means for wireless communication with the on-board computer of the ship, for example satellite Internet communication means, to dynamically render the data representative of the operational energy losses of the ship. These wireless communication means may be replaced with a data transfer via a physical medium, such as a data storage flash drive, when the rendering is performed only once the ship has arrived at the destination.

The determination device according to the invention, the determination system according to the invention, the supervision system according to the invention and the computer program according to the invention, comprise advantages similar to those of the determination method according to the invention and of the supervision method according to the invention.

Other features and advantages of the invention will appear better throughout the following description, on the one hand, and from several embodiments given for non-limiting indicative purposes with reference to the appended schematic drawings, on the other hand, wherein:

[fig 1] shows steps of a method according to the invention, for determining data representative of operational energy losses in a liquefied gas transport ship, over a time interval, in one embodiment of the invention, and of the steps of a supervision method implementing this determination method, in this embodiment of the invention,

[fig 2] shows a determination system according to the invention, in this embodiment of the invention, comprising means adapted to implement the determination method according to the invention,

[fig 3] shows a graphical interface allowing rendering the data determined by the methods of Figure 1, in this embodiment of the invention, when a liquefaction system of the ship has been activated over the time interval, and

[fig 4] shows the graphical interface of Figure 3, when the liquefaction system of the ship has been deactivated over the time interval.

In one embodiment of the invention shown in Figures 1 to 4, a determination method 10 shown in Figure 1 allows delivering data representative of operational energy losses D_f , D_s over a time interval, of a ship 40 shown in Figure 2. This determination method 10 is part of a more general method for supervising operational data related to the tanks 42 of the ship 40. For example, the selected or predetermined time interval is one day, one hour, a shorter or longer time interval. For example, the time interval corresponds to a period of time necessary for the ship to make a trip or a trip portion, selected by a user of the determination method 10. The ship 40 is a liquefied gas transport ship, this gas being, in this embodiment of the invention, liquefied natural gas. However, in one variant, this gas is for example liquid hydrogen or another type of gas.

The ship 40 stores the liquefied gas at -163°C and at a pressure close to atmospheric pressure in sealed and heat-insulated tanks 42. Each tank 42 is filled with liquefied gas up to the liquid level referenced 46, the space in the tank above this liquid level 46, called tank headspace, being filled with evaporated gas. The liquefied gas present in liquid and gaseous form in the tanks 42 of the ship 40 represents an amount of energy transported by the ship 40. This amount of energy decrease as the ship progresses in its trip, because of the gas consumption by the consumers of the ship, gas losses by evaporation and energy losses related to the pressure and temperature variations of the liquefied natural gas, these variations possibly being of various origins such as swell, weather, thermal resistance of the tanks, gas drawing by the consumers of the ship 40, etc. Nevertheless, the ship 40 comprises a liquefaction system allowing liquefying a portion of the evaporated gas in the tank headspace and thus saving a gas loss.

The determination method 10 according to the invention allows determining:

- a piece of data representative of an actual operational energy loss D_f , corresponding to an actual energy loss during the time interval, with respect to a reference energy as explained hereafter; this piece of data representative of an actual operational energy loss D_f is calculated, in this embodiment of the invention, whether the liquefaction system is active or not over the time interval. This time interval may be modified so as to correspond to one single active or deactivated state of the liquefaction system; and

- a piece of data representative of an estimated operational energy loss D_s , calculated only when the liquefaction system is active over the time interval, and corresponding to an energy loss during the time interval, that would have been observed if the liquefaction system had not been activated over the time interval, this energy loss also relating to a reference energy.

In this embodiment of the invention, the determination method 10 is implemented in a hardware and/or software manner in a system for determining data representative of operational energy losses D_f , D_s , referenced in Figure 2 and now described, the steps of the determination method 10 allowing obtaining the data representative of operational energy losses D_f , D_s being described afterwards. The determination system 50 is part of a more general system for supervising operational data related to the tanks of the ship, implementing the supervision method 11 according to the invention in a hardware and/or software manner.

The determination system 50 comprises an on-board computer 52, which receives measurements originating from various sensors present in the ship 40, in particular temperature sensors 54 measuring the temperature of the liquefied gas in the tanks 42 and at least one mass flowmeter 56 measuring the mass of gas sent to the consumers of the ship during the time interval.

The determination system 50 also comprises a remote server 55 represented in the Internet "cloud" 60, which dynamically receives measurements from the temperature sensors 54 and from the mass flowmeter 56, sent by the on-board computer 52 in a message m_1 . For sending these measurements, the on-board computer 52 comprises for example means for connection to the satellite Internet. For receiving the measurements, the remote server 55 comprises, for example, a wired Internet connection. For example, the remote server 55 receives measurements from several gas transport ships and stores them in a database 57. It comprises calculation, addition and addition means, allowing implementing the

calculation steps of the determination method 10 according to the invention and determining the data representative of operational energy losses D_f , D_s of the ship 40 over the time interval, as described hereafter. These means comprise at least one processor of the server 55, adapted to read data stored in the database 57.

The determination system 50 also comprises a terminal 58, for example a laptop computer or a multimedia mobile telephone, comprising means for displaying the data representative of operational energy losses D_f , D_s provided by the remote server 55, these display means comprising in particular a screen. In this example of use of the invention, this terminal 58 is on the ship 40, but could also use the invention on land. Hence, it uses satellite Internet connection means to send a message m_2 to the remote server 55, this message m_2 containing a request to send the data representative of operational energy losses D_f , D_s over the time interval. On reception of the message m_2 , the remote server 55 sends, in a message m_3 , the data representative of operational energy losses D_f , D_s to the terminal 58.

Returning to Figure 1, the determination method 10 comprises a first step of calculating a first piece of data D_1 representative of an amount of energy consumed over the time interval, as a function of a measurement provided by the mass flowmeter 56. This mass flowmeter 56 supplies a total flow rate φ of gas consumption by the consumers 44 of the ship, shown in Figure 2, including in particular main engines of the ship 40, auxiliary engines of the ship 40 and a flare burning the non-recovered evaporated gas, used when the liquefaction system is deactivated. Alternatively, several mass flowmeters are used, for example one for each consumer.

It should be noted that the use of the mass flowmeters of the consumers to estimate a consumed mass of gas is more accurate than observing the difference in liquid level over the time interval. Indeed, the measurements of liquid levels could be very noisy because of the movements of liquid in the tanks 42.

In a case of use of the embodiment of the invention, the first piece of data D_1 is a percentage of energy consumed over one day, calculated as follows, by first calculation means of the server 55:

$$D_1 = \frac{\int_{t_1}^{t_2} \varphi dt * L_{hv}}{N * t} * 100$$

With:

- * the multiplication operator

- t the duration of the time interval in days,
- t_1 the beginning of the time interval,
- t_2 the end of the time interval,
- φ the flow rate provided by the mass flowmeter 56 in kilograms per day,
- 5 - L_{hv} is an average of the latent heat of vaporization of the gas between the beginning and the end of the time interval, in kilojoules per kilogram, and
- N is a reference energy in kilojoules.

For example, the reference energy N is the amount of energy that the liquefied gas represents in the tanks 42 at the beginning of a period of use of the determination method 10, identical to the beginning of the time interval or earlier:

$$N = d1 * V1 * L1$$

where

- $d1$ is the density in kilograms per cubic meter, of the liquefied gas in the tanks 42 at the beginning of the period of use of the determination method 10,
- 15 - $V1$ is the volume in cubic meters of the liquefied gas in the tanks 42 at the beginning of the period of use of the determination method 10, and
- $L1$ is the latent heat of vaporization of the liquefied gas in the tanks 42 at the beginning of the period of use of the determination method 10, in kilojoules per kilogram.

Alternatively, the reference energy N is considered equal to the amount of energy loaded in the tanks 42 immediately after the end of filling thereof:

$$N = d2 * V2 * L2$$

where

- $d2$ is the density in kilograms per cubic meter, of the liquefied gas in the tanks 42 just after filling thereof,
- 25 - $V2$ is the volume in cubic meters of the liquefied gas in the tanks 42 just after filling thereof, and
- $L2$ is the latent heat of vaporization of the liquefied gas in the tanks 42 just after filling thereof, in kilojoules per kilogram.

In still another variant, the reference energy N is considered equal to the amount of energy loaded in the tanks 42 just after filling thereof, in the case where the liquefied gas is pure methane:

$$N = dm * V2 * Lm$$

where

- dm is the density of pure methane in kilograms per cubic meter, and
- Lm is the latent heat of vaporization of pure methane, in kilojoules per kilogram.

5 It should be noted that in this embodiment, by “pure methane”, it should be herein understood that the gas is not formed from a mixture of methane with another gas such as propane, for example, but is formed solely from methane, whilst considering impurities.

10 This last variant has the advantage of not depending on the reference energy of the measurement period but only on the volume of the liquefied gas initially loaded in the ship.

A second step of the determination method 10 is a step 14 of calculating a second piece of data D2, representative of an energy variation related to the temperature variation of the liquefied gas present in the tanks 42, as a function of
15 temperature variations of the liquefied gas in the tanks 42 measured over the time interval.

This second piece of data D2 reflects an energy variation related to the temperature changes in the tanks 42, and corresponds to a negative energy variation if the temperature has decreased (for example because of a decrease in pressure)
20 and therefore to an amount of energy provided by the LNG, or, if the temperature has increased, to a positive energy variation and therefore to an amount of energy absorbed by the LNG.

In the case of use of this embodiment of the invention, the second piece of data D2 is a percentage of energy stored or taken over the considered day,
25 calculated as follows, by second calculation means of the server 55:

$$D2 = \frac{Vf * df * Cp * (T2 - T1)}{N * t} * 100$$

with:

- df is the density in kilograms per cubic meter, of the liquefied gas in the tanks 42 at the end of the time interval,
- 30 - Vf is the volume in cubic meters of the liquefied gas in the tanks 42 at the end of the time interval,

- C_p is an average of the specific heat (also called the specific heat capacity) of the liquefied gas between the beginning and the end of the time interval, in kilojoules per kilogram and per degree Celsius,

5 - T_2 is an average of temperature measurements, in degrees Celsius, of the liquefied gas in the tanks 42 at the end of the time interval, and

- T_1 is an average of temperature measurements, in degrees Celsius, of the liquefied gas in the tanks 42 at the beginning of the time interval.

Alternatively, the second piece of data D2 is calculated by summing up the energy percentages related to the temperature variation of the liquefied natural gas, therefore to an energy stored or lost over the time interval, these percentages being
10 calculated individually on each of the tanks 42. The temperature measurements at the beginning of the time interval, on the one hand, and at the end of the time interval, on the other hand, are averaged for each tank 42 in order to have a piece of data representative of the temperature in the tank at the beginning or at the end of
15 the time interval. The different temperature measurements in one of the tanks 42 at a given time point, which are averaged, correspond for example to measurements made by different temperature sensors spaced apart along a liquefied gas unloading mast, present in each tank 42.

A third step of the determination method 10 is a step of adding
20 piece of data D2 to the first piece of data D1 resulting in the piece of data representative of an actual operational energy loss Df in the ship 40 over the time interval, the addition step being implemented by addition means of the server 55:

$$Df = D1 + D2$$

In the case of use of this embodiment of the invention, the piece of data
25 representative of an actual operational energy loss Df corresponds to a percentage of energy lost with respect to a reference energy, over the considered day. It corresponds to an active operational performance if the liquefaction system has been activated over this day, or to a passive operational performance if the liquefaction system has been deactivated over this day.

30 A fourth step of the determination method 10 is a step of calculating 18 a third piece of data D3 representative of an amount of energy saved by the liquefaction system over the time interval. It is assumed, in this case of use of the invention, that the liquefaction system has been activated over the time interval, and has therefore allowed avoiding losing a mass of evaporated gas in the tanks 42 that has been

larger than the needs of the consumers 44, by reliquefying it. Otherwise, this mass would probably have been burnt by the flare. The fourth step of the determination method 10 is implemented by third calculation means of the server 55.

In the case of use of this embodiment of the invention, the third piece of data D3 is a percentage of energy saved over the considered day:

$$D3 = \frac{\int_{t1}^{t2} \emptyset dt * L_{hv}}{N * t} * 100$$

where $\emptyset$ is the mass flow rate in kilograms per day, of the reliquefied gas thanks to the liquefaction system. A flowmeter connected to the liquefaction system allows providing this value.

A fifth step of the determination method 10 is a step of adding 20 the third piece of data D3 to the piece of data representative of an actual operational energy loss Df, providing the piece of data representative of an estimated operational energy loss Ds, the fifth step of the determination method 10 being implemented by addition means of the server 55:

$$Ds = D3 + Df$$

Hence, the piece of data representative of an estimated operational energy loss Ds corresponds to an estimation of the operational energy loss that would have occurred over the day if the liquefaction system had not been activated. Hence, it corresponds to a passive operational performance estimated a posteriori.

In a case of use where the liquefaction system is deactivated, we have:

$$D3 = 0 \Rightarrow Ds = Df$$

In the latter case, the piece of data representative of an estimated operational energy loss Ds therefore corresponds to the piece of data representative of an actual operational energy loss Df, and no longer to an estimate.

In the case of a ship 40 equipped with a liquefied gas vaporization device, the method for determining data representative of operational energy losses may further comprise an optional step of calculating a fifth piece of data D5 representative of an amount of energy of the liquefied gas pumped from the tank and intended to pass through the vaporization device over the time interval and a step of subtracting the fifth piece of data D5 from the piece of data representative of the actual operational energy loss Df.

The fifth piece of data D5 corresponds to the “forced BOR”. This consists of an amount of energy related to the mass of the liquefied gas pumped from the tank and

directed through the vaporization device, calculated as follows, by fifth calculation means of the server 55:

$$D5 = \frac{\int_{t1}^{t2} \Phi dt * L_{hv_LG}}{N * t} * 100$$

With:

- 5 - * the multiplication operator,
- t the duration of the time interval in days,
- $t1$ the beginning of the time interval,
- $t2$ the end of the time interval,
- Φ the flow rate provided by a mass flowmeter downstream of the vaporization
- 10 device in kilograms per day,
- L_{hv_LG} an average of the latent heat of vaporization of the liquefied gas between the beginning and the end of the time interval, in kilojoules per kilogram, and
- N a reference energy in kilojoules, already described hereinabove.

15 The method for determining data representative of operational energy losses may also comprise an optional step of calculating a sixth piece of data D6 representative of an energy variation of the gas phase of the liquefied gas present in the tank, as a function of a pressure and temperature variation in the ship over the time interval, and a step of adding the sixth piece of data D6 to the piece of data

20 representative of the actual operational energy loss Df.

The sixth piece of data D6 corresponds to the “ballast BOR” or “pressure BOR”. This consists of an amount of energy related to the gas phase of the liquefied gas present in the tank, and which varies as a function of the pressure and the temperature in the tank over the time interval, which, as a non-limiting example,

25 could be calculated as follows, by sixth calculation means of the server 55:

$$D6 = \frac{0,5 * (L_{hv}(t1) + l_{hv}(t2)) * \Delta mp}{L_{hv} * d * V * t}$$

Δmp representing the mass of evaporated gas contributing to the rise of pressure in the tank and could be determined based on the ideal gas law:

$$\Delta mp = \frac{1}{R} * (M_{BOG}(t2) * \frac{P(t2) * V_{BOG}(t2)}{T_{BOG}(t2)} - M_{BOG}(t1) * \frac{P(t1) * V_{BOG}(t1)}{T_{BOG}(t1)})$$

30 With

- * the multiplication operator,

- t the duration of the time interval in days,
- $t1$ the beginning of the time interval,
- $t2$ the end of the time interval,
- d is the average density in kilograms per cubic meter, of the liquefied gas in

5 the tanks 42 over the time interval t ,

- V is the average volume in cubic meters of the liquefied gas in the tanks 42 over the time interval t ,

- L_{hv} an average of the latent heat of vaporization of the gas between the beginning and the end of the time interval, in kilojoules per kilogram, ($L_{hv}(t1)$,
10 respectively $l_{hv}(t2)$), corresponding to the latent heat of vaporization of the gas at the time point $t1$, respectively $t2$),

- R is the universal constant of ideal gases,

- $P(t1)$, respectively $P(t2)$, is the pressure in the tank at the time point $t1$, respectively $t2$,

- $V_{BOG}(t1)$, respectively $V_{BOG}(t2)$, is the volume of the gas evaporated in the tank at the time point $t1$, respectively $t2$,

- $T_{BOG}(t1)$, respectively $T_{BOG}(t2)$, is the temperature of the gas evaporated in the tank at the time point $t1$, respectively $t2$,

- $M_{BOG}(t1)$, respectively $M_{BOG}(t2)$, is the molar mass of the gas evaporated in
20 the tank at the time point $t1$, respectively $t2$.

The calculation of the sixth piece of data D6 contributes to a better determination of the operational energy losses over the selected time interval. The sixth piece of data D6 takes account of the pressure variations in the tank which could reflect a potentially non-negligible mass loss, particularly in a ballast journey
25 during which the volume of gas in the tank is large.

In parallel with these first five steps and optional steps of the determination method 10 according to the invention, the supervision method 11 according to the invention implements an additional step of calculating 22 a fourth piece of data D4 representative of an energy loss in the tanks 42 as a function of a volume variation of
30 the liquefied gas over the time interval.

In the case of use of the embodiment of the invention, D4 is a percentage of energy lost over the considered day, calculated as follows:

$$D4 = \frac{(Vi - Vf)}{Vi * t} * 100$$

where V_i is the volume in cubic meters of the liquefied gas in the tanks 42 at the beginning of the time interval.

Alternatively, D4 may be calculated by replacing V_i in the denominator with a volume of the liquefied natural gas just after loading the ship, or with a filling volume of the tanks at a predetermined percentage, for example 95% or 98%.

This calculation gives an order of magnitude of the total energy loss in the tanks 42 over the time interval. Indeed, this calculation is not accurate because the evaporated amount of liquefied gas depends considerably on the operations of the crew of the ship. For example, if the crew decides to run at a high speed, it might happen that the gas pressure in the tanks 42 drops, thereby forcing the evaporation of the liquefied gas. In this manner, the evaporated amount of liquefied gas will be larger. On the contrary, if the crew slows down, or if the ship is stopped, the gas needs of the different consumers will be quite probably less significant than the gas emitted by the tanks 42 by evaporation. Thus, the pressure will rise in the tanks 42 and the evaporated amount of gas will be smaller.

This is why the invention considers the temperature variation of the liquefied gas, because this temperature variation is closely related to the evaporated amount of gas. If the latter is very large, then the temperature of the liquefied gas will quite probably drop. On the other hand, if the gas consumption is low, the temperature of the liquefied gas as well as the gas pressure in the tanks 42 should rise.

A sixth step of the determination method 10, common to the supervision method 11, is a step of rendering 24 the previously calculated data D1, D2, D3, D4, Ds, Df (and optionally D5, D6) on a graphical interface displayed on a screen of the terminal 58. Of course, in other embodiments of the invention, this rendering could be done otherwise, for example in a textual or voice manner on the terminal 58 or on another element of the determination system 50.

It should be noted that steps 12 to 24 are not necessarily executed in the described order, the first step 12, the second step 14, the fourth step 18 and the sixth step 22 could in particular be performed independently in parallel with one another. Preferably, steps 12 to 22 are repeated to provide data corresponding to several time intervals, for example they are executed at the end of each day of a trip made by the ship 40.

Finally, the determination method according to the invention may comprise a step of applying a corrective coefficient to one of the data delivered by the calculation

means to take account of related physical phenomena that could affect the calculation of the data. For example, in the case of the third piece of data D3 representative of an amount of energy saved by the liquefaction system over the time interval, a corrective coefficient may be applied to take account of the fact that, after liquefaction, the return of the gas into the tank could be accompanied by a re-evaporation of a liquefied gas fraction. This re-evaporation contributes to attenuating the amount of energy actually saved by the liquefaction system. The corrective coefficient allows taking account of this effect. The impact of the re-evaporation may be determined by means of calculations known to a person skilled in the art. The corrective coefficient may be tabulated on the basis of calculations carried out beforehand as a function of the surrounding parameters of the tank or it may be calculated by the calculation means associated with the data when knowing the surrounding parameters of the tank.

Figure 3 shows a screenshot 30 of the terminal 58, showing the graphical interface split into five areas 1 to 5.

The area 1 is a map of the world on which the trip made by the ship 40 is shown. A graphical button on this map enables a user of the determination method 10 to select the entire trip or a portion of the latter.

The area 2 displays fixed data related to the trip and to the ship 40, in particular under the entry "id" the name of the boat ("Messi" in this example of use), under the entry "ref" a reference of the trip ("Voyage" in this example of use), GPS coordinates (standing for "Global Positioning System") of the point of departure and of the point of arrival of the trip, the corresponding distance, a date of departure and a corresponding date of arrival, the duration in hours of the trip, as well as the capacity of the ship 40, its density and an indicator of a loaded journey or of a return using a ballast, the indicator being set at "L" if the ship is in a loaded journey.

The area 3 comprises graphical tabs that could be selected by the user, allowing visualizing on the area 3, when the corresponding graphical tab is selected, a graph representing:

- a flow rate $v1$ of evaporated gas sent to the liquefaction system over time, in kilograms per hour,

- a cumulative mass of gas $v2$ lost over time, corresponding to a piece of data representative of an actual operational energy loss calculated over the selected trip portion in kilograms of gas rather than a percentage,

- a mass flow rate of consumed gas v8 over time, corresponding for example to data representative of actual operational energy losses calculated for each day of the selected trip portion in tons per day rather than percentages,

- a density v7 of the liquefied gas in the tanks 42 over time,

- a temperature v5 of the liquefied gas in the tanks 42 over time,

- a pressure v6 of the gas evaporated in the tanks 42 over time,

- a volume v4 of the liquefied gas in the tanks 42 over time, and

- a speed v3 of the ship 40 over time.

On the screenshot 30, the user has selected the tab corresponding to the flow rate v1 of evaporated gas sent to the liquefaction system during the selected trip portion. On the graph corresponding to the flow rate v1, the periods corresponding to an activation of the liquefaction system, for which the flow rate of gas sent to the liquefaction system is non-zero, are gray. This is due to the fact that, in the area 4, the user has selected a graphical button B1 corresponding to the activation periods of the liquefaction system over the selected trip portion.

The area 4 comprises a waterfall chart G1 representing:

- by a first histogram bar at a first location, an average of the first data D1 calculated by the determination system 50 for each day of the selected trip portion, during which the liquefaction system has been active, denoted “consumed BOR” or “mass BOR”,

- by a second histogram bar at a second location, an average of the second data D2 calculated by the determination system 50 for each day of the selected trip portion, during which the liquefaction system has been active, denoted “BOR due to the temperature variation of the LNG” or “rate due to the conditioning of the ship”,

- by a third histogram bar at a third location, the sum between the average represented at the first location and the average represented at the second location, denoted “active BOR”,

- by a fourth histogram bar at a fourth location, an average of the third data D3 calculated by the determination system 50 for each day of the selected trip portion, during which the liquefaction system has been active, denoted “reliquefied BOR”,

- by a fifth histogram bar at a fifth location, the sum between the sum represented at the third location and the average represented at the fourth location, denoted “passive BOR”, and

- by a sixth histogram bar at a sixth location, an average of the fourth data D4 calculated by the supervision system for each day of the selected trip portion, during which the liquefaction system has been active, denoted “volumetric BOR”.

Hence, the waterfall chart represents mean percentages of energy losses or savings per day of the selected trip portion. Alternatively, it represents percentages of energy losses or savings over the entirety of the selected trip portion, on a waterfall chart G2, or a cumulative sum of energy losses or savings over the entirety of the selected trip portion, on a waterfall chart G3.

In the waterfall chart G1, the first bar extends from a zero ordinate up to an extreme high ordinate, the second bar extends from the extreme high ordinate of the first bar down to an extreme low ordinate, and the third bar extends from the extreme low ordinate of the second bar to a zero ordinate. Thus, the construction of the piece of data representative of an actual operational energy loss Df as the sum between the first piece of data D1 and the second piece of data D2 is visually represented. It should be noted that the extreme high ordinate of the first bar could become an extreme low ordinate of the second bar when the second piece of data D2 is representative of an energy loss rather than an energy saving.

Similarly, the fourth bar extends from an extreme low ordinate equal to the extreme low ordinate of the second bar and also to an extreme high ordinate of the third bar, up to an extreme high ordinate, and the fifth bar extends from a zero ordinate to the extreme high ordinate of the fourth bar. Thus, the construction of the piece of data representative of an estimated operational energy loss Ds as the sum between the third piece of data D3 and the actual operational energy loss Df is visually represented.

Finally, the area 5 represents scales of values ranging from the green for low values, to the red for high values, an arrow on each bar showing the measured value:

- on a first scale E1, the speed of the ship is represented,
- on a second scale E2, the speed of the main engines of the ship 40 is represented, and
- on a third scale E3, the pressure in the tanks 42 is represented.

In Figure 4, a screenshot 32 of the graphical interface corresponds to the case where the user has selected in the area 3, the tab corresponding to the flow rate v1 of gas sent to the liquefaction system during the selected trip portion, and where the

user has selected in the area 4, a graphical button B2 corresponding to the periods of deactivation of the liquefaction system over the selected trip portion.

Therefore, on the graph corresponding to the flow rate v_1 , the periods for which the reliquefied gas flow rate is zero are gray. In addition, a new waterfall chart is shown in the area 4 and now comprises only four histogram bars:

- On the first location, a first histogram bar denoted “consumed BOR” or “mass BOR”, represents a new average of first data D1 calculated by the determination system 50 for each day of the selected trip portion, during which the liquefaction system has been deactivated,

- On the second location, a second bar denoted “BOR due to the temperature variation of the LNG” or “rate due to the conditioning of the ship”, represents a new average of second data D2 calculated by the determination system 50 for each day of the selected trip portion, during which the liquefaction system has been deactivated,

- On the third location, no bar is present but the value 0% is displayed, this value being denoted “active BOR” on this third location,

- On the fourth location, no bar is present but the value 0% is displayed, corresponding to a zero percentage of energy saved by the liquefaction system, this value being denoted “reliquefied BOR” on this fourth location,

- On the fifth location, a fifth histogram bar denoted “passive BOR” represents the sum between the new average represented on the first location and the new average represented on the second location, and therefore the data representative of an operational energy loss D_f , and

- On the sixth location, a sixth histogram bar denoted “volumetric BOR” represents a new average of fourth data D4 calculated by the supervision system for each day of the selected trip portion, during which the liquefaction system has been deactivated.

In this new waterfall chart, the first, second and fifth bars are arranged similarly to the waterfall chart of Figure 3, to visualize the fact that the fifth bar representative of an actual operational energy loss is constructed as the sum between the first bar representative of a consumed energy and the second bar representative of an energy variation related to the temperature change of the liquefied natural gas.

Hence, the data representative of an actual operational energy loss D_f is represented at the fifth location, where the piece of data representative of an estimated operational energy loss D_s is represented in Figure 3. Indeed, this fifth location is dedicated to a passive operational performance, corresponding to an operating mode of the ship 40 in which the liquefaction system is deactivated. Similarly, the third location is dedicated to an active operational performance D_g , corresponding to an operating mode of the ship 40 in which the liquefaction system is active. Therefore, this active operational performance D_g is equal to the piece of data representative of the actual operational energy loss D_f in Figure 3, but is equal to the zero value in Figure 4.

Finally, in the area 4, a graphical button B3 allows visualizing a waterfall chart showing mean percentages of energy lost or saved per day, throughout the days of the selected trip portion, whether the liquefaction system is active or not. In this waterfall chart, the third location of the graph dedicated to an active operational performance will provide a first piece of data representative of an actual operational energy loss D_f over all of the time intervals for which the liquefaction system has been active, and the fifth location of the graph dedicated to a passive operational performance will provide a second piece of data representative of an actual operational energy loss D_f over all of the time intervals for which the liquefaction system has been active and inactive, this second representative piece of data being obtained by adding the piece of data representative of the energy saved by reliquefying over the entire trip portion, to the first piece of data representative of an actual operational energy loss D_f .

The same principle applies with the fifth and sixth data D_5 , D_6 when these are taken into account in the determination method of the invention.

Of course, the invention is not limited to the examples that have just been described and many modifications could be made to these examples without departing from the scope of the invention. In particular, the features of the different embodiments or variants of the invention considered in this application could be combined to carry out the invention, insofar as these embodiments or variants are not incompatible with each other.

CLAIMS

1. A method for determining (10) data representative of operational energy losses (Df, Ds) over a time interval, of a liquefied gas transport ship (40), this energy
 5 being initially stored in the form of liquefied gas and evaporated gas in at least one tank (42) of the ship (40), the ship (40) being equipped with a system for liquefying the evaporated gas, the determination method (10) comprising steps of:

- calculating (12) a first piece of data (D1) representative of an amount of energy consumed over the time interval, as a function of at least one measurement
 10 relating to the activity of at least one energy consumer (44) of the ship (40),

- calculating (14) a second piece of data (D2) representative of an energy variation of the liquefied gas present in the tank, as a function of a temperature variation of the liquefied gas in the tank (42) over the time interval,

- adding (16) the second piece of data (D2) to the first piece of data (D1)
 15 resulting in a piece of data representative of an actual operational energy loss (Df) in the ship (40),

the determination method (10) being characterized in that it further comprises, when the liquefaction system is activated over the time interval:

- a step of calculating (18) a third piece of data (D3) representative of an
 20 amount of energy saved by the liquefaction system over the time interval, and

- a step of adding (20) the third piece of data (D3) to the piece of data representative of an actual operational energy loss (Df), resulting in a piece of data representative of an estimated operational energy loss (Ds) that would have been observed without the activation of the liquefaction system.

25
 2. The method for determining (10) data representative of operational energy losses according to claim 1, the ship (40) being equipped with a device for vaporizing the liquefied gas, the method further comprising a step of calculating a fifth piece of data (D5) representative of an amount of energy of the liquefied gas pumped from
 30 the tank and intended to pass through the vaporization device over the time interval and a step of subtracting the fifth piece of data (D5) from the piece of data representative of the actual operational energy loss (Df).

3. The method for determining (10) data representative of operational energy losses according to claim 1 or 2, further comprising a step of calculating a sixth piece of data (D6) representative of an energy variation of the gas phase of the liquefied gas present in the tank, as a function of a pressure and temperature variation in the tank over the time interval, and a step of adding (XX) the sixth piece of data (D6) to the piece of data representative of the actual operational energy loss (Df).

4. The method for determining (10) data representative of operational energy losses according to any one of claims 1 to 3, wherein each of the first, second, third, fifth, sixth data (D1, D2, D3, D5, D6) as well as the piece of data representative of an actual operational energy loss (Df) and the piece of data representative of an estimated operational energy loss (Ds) corresponds to a ratio between, on the one hand, an amount of energy lost over the time interval and, on the other hand, a reference amount of energy selected from among:

- an amount of energy calculated at the beginning of a period of use of the determination method (10), or
- an amount of energy loaded in the ship (40).

5. A method for supervising (11) operational data related to at least one tank (42) of a liquefied gas transport ship (40), characterized in that it implements the method for determining (10) data representative of operational energy losses according to any one of claims 1 to 4, and in that it comprises a step of calculating (22) a fourth piece of data (D4) representative of a volume variation of the liquefied gas in the tank (42) over the time interval.

6. A device for determining (55) data representative of operational energy losses, comprising means for implementing the determination method (10) according to any one of claims 1 to 4, or the supervision method (11) according to claim 5.

7. A system for determining (50) data representative of operational energy losses over a time interval, of a liquefied gas transport ship (40), this energy being initially stored in the form of liquefied gas and evaporated gas in at least one tank (42) of the ship (40), the ship (40) being equipped with a system for liquefying the evaporated gas, the determination system (50) comprising:

- first means for calculating a first piece of data (D1) representative of an amount of energy consumed over the time interval, as a function of at least one measurement relating to the activity of at least one energy consumer (44) of the ship (40),

5 - second means for calculating a second piece of data (D2) representative of an energy variation of the liquefied gas present in the tank (42), as a function of a temperature variation of the liquefied gas in the tank (42) over the time interval,

 - means for adding the second piece of data (D2) to the first piece of data (D1), resulting in a piece of data representative of an actual operational energy loss
10 (Df) in the ship (40),

 the determination system (50) being characterized in that it further comprises:

 - third means for calculating a third piece of data (D3) representative of an amount of energy saved by the liquefaction system over the time interval, when the liquefaction system is activated over the time interval, and

15 - means for adding the third piece of data (D3) to the piece of data representative of an actual operational energy loss (Df), resulting, when the liquefaction system is activated over the time interval, in a piece of data representative of an estimated operational energy loss (Ds) that would have been observed without the activation of the liquefaction system.

20 8. The determination system (50) according to claim 7, the ship (40) being equipped with a device for vaporizing the liquefied gas, further comprising fifth means for calculating a fifth piece of data (D5) representative of an amount of energy of the liquefied gas pumped from the tank and intended to pass through the vaporization
25 device over the time interval and additional means for subtracting the fifth piece of data (D5) from the piece of data representative of the actual operational energy loss (Df).

30 9. The determination system (50) according to claim 7 or 8, further comprising sixth means for calculating a sixth piece of data (D6) representative of an energy variation of the gas phase of the liquefied gas present in the tank, as a function of a pressure and temperature variation in the tank over the time interval, and additional means for adding the sixth piece of data (D6) to the piece data representative of the actual operational energy loss (Df).

10. The determination system (50) according to any one of claims 7 to 9, comprising a human-machine interface comprising display means (58) adapted to provide a representation of the first, second, third, fifth and sixth data (D1, D2, D3, D5, D6), as well as data representative of the actual (Df) and estimated (Ds) operational energy losses, wherein the piece of data representative of an actual operational energy loss (Df) is visualized as a sum between at least two among the first, second, fifth and sixth data (D1, D2) and, when the liquefaction system is activated over the time interval, the piece of data representative of an estimated operational energy loss (Ds) is visualized in the form of a cumulation of the third piece of data (D3) and of the piece of data representative of the actual operational energy loss (Df).

11. The determination system (50) according to the preceding claim, wherein the representation is a waterfall chart (4).

12. The determination system (50) according to the preceding claim, wherein the display means (58) are adapted to represent the piece of data representative of the actual operational energy loss (Df) at a first location of the waterfall chart (4) when the liquefaction system is activated over the time interval, or at a second location of the waterfall chart (4), distinct from the first location, when the liquefaction system is deactivated over the time interval, the piece of data representative of an estimated operational energy loss (Ds) being shown by the display means (58) at the second location when the liquefaction system is activated over the time interval.

13. The determination system (50) according to any one of claims 10 to 12, wherein the human-machine interface of the determination system (50) further comprises means for selecting (1) at least one portion of a trip made by the ship (40), and means for selecting (B1) first time intervals during which the liquefaction system has been activated over this trip portion, the display means (58) being adapted to represent when the first time intervals are selected by a user of the determination system (50):

- an average of each piece of data among the first, second, fifth and sixth data (D1, D2, D5, D6) delivered by the means for calculating said piece of data for each of the first time intervals,

- an average of data representative of actual operational energy losses (Df) delivered by the addition means for each of the first time intervals,

- an average of third data (D3) delivered by the third calculation means for each of the first time intervals, and

- an average of data representative of estimated energy operational losses (Ds) delivered by the addition means for each of the first time intervals.

14. The determination system (50) according to the preceding claim, wherein the human-machine interface of the determination system (50) further comprises means for selecting (B2) second time intervals during which the liquefaction system has been deactivated over this trip portion, the display means (58) being adapted to represent when the second time intervals are selected by a user of the determination system (50):

- an average of each piece of data among the first, second, fifth and sixth data (D1, D2, D5, D6) delivered by the means for calculating said piece of data for each of the second time intervals, and

- an average of data representative of actual operational energy losses (Df) delivered by the addition means for each of the second time intervals.

15. The determination system (50) according to any one of claims 10 to 14, wherein the human-machine interface further comprises means for selecting at least one tab related to an operational piece of data relating to the liquefied, evaporated, reliquefied or consumed gas in the tanks (42), adapted to make the display means (58) display a graph (3) of values corresponding to the selected tab, the values being those of the operational piece of data over one or more time interval(s) and being recorded in a memory of the determination system (50).

16. A system for supervising operational data related to at least one tank (42) of a liquefied gas transport ship, characterized in that it comprises the system for determining (50) data representative of operational energy losses according to any one of claims 7 to 15, and in that it comprises means for calculating a fourth piece of

data (D4) representative of a volume variation of the liquefied gas in the tank (42) over the time interval.

17. A computer program comprising program code instructions for executing
5 the steps of the determination method (10) according to any one of claims 1 to 4,
when said program is executed on one or more processor(s).