

CLAIMS

1. A method for calculating in real-time the duration of autonomy of a non-refrigerated tank and defined by a set pressure of valves p_{valve} , a shape of said tank and dimensions of said tank, as well as the boil off rate of said tank, said tank containing natural gas divided into:
 - a layer of natural gas in liquid state (l), defined at a given instant t by its temperature $T_{\text{liq}}(t)$, its composition $x_{\text{liq}}(t)$, and the filling rate of the tank by said natural gas layer;
 - a natural gas layer in gaseous state (g), defined at a given instant t by its temperature $T_{\text{gas}}(t)$ and its composition $x_{\text{gas}}(t)$, and a pressure $p(t)$;
- 15 said method being characterised in that it consists of an algorithm comprising the following steps:
 - A. at an instant t_0 , the physical parameters $p(t)$, $T_{\text{gas}}(t)$, $x_{\text{gas}}(t)$, $T_{\text{liq}}(t)$, $x_{\text{liq}}(t)$ of said natural gas layers are initialised, by measuring using pressure and temperature sensors, the pressure of the gas $p(t_0)$, and the temperature of the liquid $T_{\text{liq}}(t_0)$; while the respective compositions of the liquid $x_{\text{liq}}(t_0)$ and gaseous $x_{\text{gas}}(t_0)$ phases are known input data corresponding either to the respective compositions of the liquid and gaseous phases at the time of the loading of the tank, or to average compositions for the type of LNG used;
 - B. for each instant t greater than t_0 , a predetermined volume of natural gas in the gaseous or liquid state is subtracted, said volume corresponding to the operating state of the tank at this instant t ; and a calculation is

made, based on the volume of natural gas remaining after subtraction, of the physical parameters $p(t)$, $T_{gas}(t)$, and $T_{liq}(t)$, using equations based on the conservation of the mass and of the energy of the liquid and gaseous natural gas contained in the tank;

5 C. as long as the pressure $p(t)$ is less than p_{valve} , the calculation of the step B is reiterated for the following instant $t+\delta t$, with a constant physical time step δt .

10 D. as soon as during the N iterations of the calculation process of $p(t)$, $p(t+\delta t)$, ..., $p(t+N*\delta t)$, the pressure $p(t+N*\delta t)$ becomes greater than or equal to p_{valve} , the calculation is stopped;

15 E. the duration of autonomy sought is equal to the total duration $N*\delta t$ elapsed by the algorithm at the moment of the stoppage of the calculation.

2. The method according to claim 1, wherein all of the steps A to D are reiterated as soon as time interval ΔT has elapsed, in order to recalculate the duration of autonomy at the instant $t_0 + \Delta T$.

3. The method according to claim 1, wherein the calculation at the step B of the physical parameters $p(t)$, $T_{gas}(t)$, and $T_{liq}(t)$ is carried out according to the steps defined as followed.

- the temperature of the liquid phase $T_{liq}(t)$ and of the gaseous phase $T_{gas}(t)$ are directly determined using the power conversion equation, with as input data the thermal capacities of the

natural gas in liquid state and of the natural gas in the gaseous state, the thermal insulation of the tank defined by the manufacturer of the tank and the temperatures at the instant $t-\delta t$ of the liquid LNG and of the gaseous LNG,

- the mass of liquid evaporated in the gaseous phase is determined by the relationship (5) according to the temperature of the liquid and the pressure determined in the preceding step at the instant $t-\delta t$:

$$(5) \quad q_{ev} = K \cdot (\Delta T_{surchauffe})^{\alpha}$$

with:

- K designating a constant relative to the LNG and always being positive,
- $\Delta T_{surchauffe}$ designating the overheating that is produced during the evaporation phenomenon in the tank of LNG,
- q_{ev} designating the standardised evaporation rate of LNG, and
- α designating a coefficient relative to the LNG, with $1 \leq \alpha \leq 2$;
- the pressure $p(t)$ of the gaseous phase is obtained by the Peng-Robinson equation, with as input data the evaporated mass of liquid, the volume of the tank and the temperature of the gas at the instant t .

4. The method according to any of claims 1 to 3, wherein the algorithm is implemented by means of a

calculator that calculates the duration of autonomy of the tank, said calculator being connected to a MMI interface that makes it possible to inform an operator as to this duration of autonomy.

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5. The system for calculating in real time, according to the method according to claim 3, the duration of autonomy of a non-refrigerated tank and defined by a set pressure of the valves p_{valve} , a shape of said tank and dimensions of said tank, as well as the boil off rate of said tank, said system comprising:

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- the tank containing liquefied natural gas divided into:

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- o a layer of natural gas in liquid state, defined at a given instant t by its temperature $T_{liq}(t)$, its composition $x_{liq}(t)$, and the filling rate of the tank by said natural gas layer in the liquid state;

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- o a natural gas layer in gaseous state, defined at a given instant t by its temperature $T_{gas}(t)$ and its composition $x_{gas}(t)$ and a pressure $p(t)$;

- pressure and temperature sensors,

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said system being characterised in that it is an onboard system further comprising:

- an onboard calculator (5) connected to said pressure (3) and temperature (4) sensors, said calculator being designed to execute the algorithm of the method according to claim 4,

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- a MMI interface (6), of the onboard dashboard type of a vehicle, interacting specifically with said onboard calculator (5), to report to an operator

(7) the duration of autonomy calculated according to the method of claim 4.

6. A vehicle comprising an NG tank and a system
5 according to claim 5.