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(71) Applicant: **LINDE AKTIENGESELLSCHAFT** [DE/DE]; Klosterhofstr. 1, 80331 München (DE).

(72) Inventor: **JARRETT, Paul**; 97 Shire Road, Morley, Leeds West Yorkshire LS27 0SN (GB).

(74) Agents: **HOFMANN, Andreas** et al.; Sendlinger Str. 2 / III, 80331 München (DE).

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(54) Title: METHOD FOR PRESSURE CONTROL AND LOW-PRESSURE DROP FILLING OF VEHICLE ONBOARD FUEL TANKS

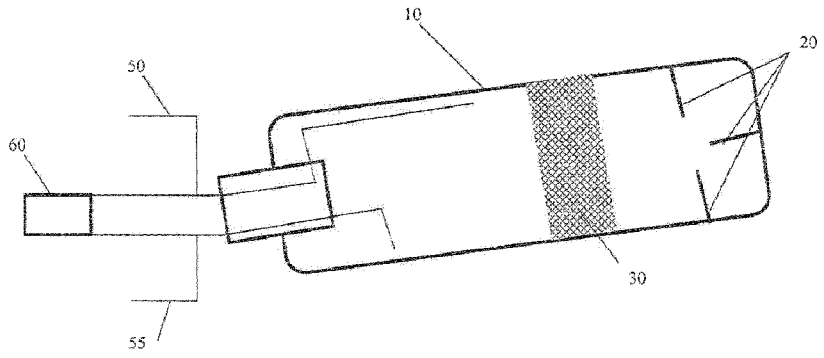


Fig. 1

(57) Abstract: In order to overcome the problems that earlier onboard fuel tanks and earlier methods for filling such onboard fuel tanks have experienced, the present invention proposes that the interior space of an onboard fuel tank (10) includes at least one of baffles (20), packing material(30) or compartments and that the onboard fuel tank (10) is arranged to be mounted at an angle within a vehicle.

METHOD FOR PRESSURE CONTROL AND LOW-PRESSURE DROP FILLING OF VEHICLE ONBOARD FUEL TANKS

Technical field of the present invention

The present invention relates to the technical field of onboard fuel tanks and to methods for filling such tanks.

Background of the present invention

Known liquefied natural gas (LNG) vehicle onboard fuel tanks comprise a horizontal liquid cylinder that has different internal and external piping arrangements. These vessels do not use vaporization coils and can only be top-filled, i. e. fresh LNG can only be added into the vapor space of the cylinder.

Some current LNG onboard tanks use an ullage chamber that has a small hole in the top and a small hole in the bottom and therefore remains mostly empty during the fill process. The ullage chamber allows an operator to fill the onboard tank hydraulically to the net volume, leaving gas trapped in the ullage chamber.

This method of filling results in a rapid pressure increase when the tank is full and a corresponding rapid drop in flow. Once the tank is filled, the small holes in the ullage chamber allow the ullage gas to be evenly distributed at the top of the net volume, and the ullage chamber fills with liquid to replace the gas lost.

There is a concern when using ullage chambers that it would be possible to overfill the onboard tank. In particular, if the onboard tank is filled and the ullage settles out but little or no fuel is used, followed by refilling the onboard tank, an overfill condition could occur. This might happen if the vehicle is filled, then goes on a short trip and returns to be refilled. In such a situation, the onboard tank would reach primary relief valve pressure very quickly (from the loss of ullage space) and liquid would be vented to the vehicle stack.

If a rapid pressure rise occurs, the secondary relief valve pressure may be reached, resulting in a vent of liquid locally, because the secondary relief valve is not vented to stack, but merely has a plastic cap. There is generally no indicator to the driver that his onboard tank is already full other than a signal based on a capacitance level probe. This is only visible in the cab when the power is on and is not visible locally at the fill connection.

Conversely, standard liquid cylinder vessels (not used for vehicle onboard fuel tanks) use vaporization coils to maintain vessel pressure through the provision of pressure raising gas. The gas product from the cylinder is first supplied by the excess pressure in the vapor space of the cylinder and then by vaporized liquid. This is accomplished by employing separate pressure raising and economizer regulators or by a combined pressure raising/economizer regulator.

Bulk delivery vehicles for cryogenic fluids employ inner baffles for the vessel that reduce kinetic energy that may be transferred to the product within the vessel during transport. In addition, these baffles reduce transfer momentum of the product in the event of a sudden change in the velocity of the delivery vehicle.

LNG engine powered vehicles have a critical supply threshold pressure below which the engine will not operate on LNG. Because of this necessary pressure, the LNG vehicle onboard fuel tank must operate at a high enough pressure to ensure that the LNG gas is delivered to the engine above the critical threshold pressure.

The known onboard fuel tanks comprise cryogenic liquid cylinder pressure vessels that are vacuum-jacketed and super-insulated. These tanks are also equipped with all the necessary piping and controls for providing the liquid or gaseous LNG safely to the vehicle fuel system. This system commonly requires a vaporizer, regulator(s) and a safety shut off valve.

As noted above, the known onboard fuel tanks do not utilize vaporization coils and they do not include a system to maintain the pressure of the onboard fuel tank as the LNG is withdrawn. Further as noted above, the known onboard fuel tanks can only be top-filled, such that fresh LNG is only added to the vapor space of the cylinder. There is usually a NRV (non-return valve) in place in the fill line.

LNG onboard tank filling is generally accomplished in one of two ways, either by pump or by decant. A pump fuelling station generally has bulk tanks that are set slightly above the LNG engine crucial threshold pressure. These tanks are kept close to saturated (no significant subcooling) with any heat inleak warming up the liquid and increasing the tank pressure.

The liquid is thus at a condition between the critical threshold pressure and the relief or vent setting of the tank. The pump can force the saturated/warmer liquid into the onboard tank (irrespective of the onboard tank pressure), resulting in full onboard tanks with LNG at or above the critical threshold pressure.

Decant refuelling employs bulk tanks set significantly above the LNG engine critical threshold pressure (for example two hundred psig or about 1379 kPa bulk tanks deliver into hundred psig or about 690 kPa onboard tanks). The bulk tanks are not maintained at specific conditions, but rather deliver the LNG cold (thirty psig or about 207 kPa saturated) with warm up occurring through natural heat inleak. The liquid is thus at a condition between the delivered state and the relief or vent setting of the onboard tank (for example 250 psig or 1724 kPa).

The pressure difference between the bulk and onboard tank forces the liquid into the onboard tank. If the pressure in the onboard tank is not sufficiently below that of the bulk tank or if the bulk tank LNG condition is not sufficiently above the pressure in the onboard tank, gas must be vented from the onboard tank in order for the fill to progress to completion.

Pump or decant fuelling can use single or dual hose transfers. Single hose transfers only transfer LNG from the bulk tank to the onboard tank (there is a non-return valve in the onboard tank fill line). A single hose transfer cannot recover vented gas from the onboard tank. Dual hose transfers can recover vented gas from the onboard tank which can then be sent to the bulk tank or returned to the filling process.

The known designs for onboard fuel tanks for LNG vehicles exhibit a number of disadvantages. In particular, if the fresh LNG being added to the vessel is too cold, then when the pressure in the onboard fuel tanks collapses the temperature remains cold enough that the equilibrium saturation pressure in below the critical supply threshold pressure and LNG can not be delivered to the engine.

The only way to increase the onboard fuel tank pressure is to add energy from an external source, for example heat transfer to the LNG from ambient temperature, or from vehicle movement, for example kinetic energy transferred to the LNG from vehicle changes in velocity.

Consequently, as the temperature of the fresh LNG increases, there is less and less cold available to collapse the pressure in the onboard fuel tank which can significantly slow the filling process. Eventually, the fresh LNG becomes too warm and pressure collapse in the onboard fuel tank stops.

This results in the pressure of the onboard fuel tank equalizing with the supply vessel pressure and the flow or filling process will stop. In order to continue the filling process, venting is then required.

In addition, if the pressure of the LNG in the onboard fuel tank is too high when filling is needed, then the filling process can also be slowed or prevented as the pressure in the onboard fuel tank may be higher than the supply vessel pressure.

There remains a need in the art for improvements to onboard fuel tanks and to filling methods for onboard fuel tanks.

Disclosure of the present invention: object, solution, advantages

Starting from the disadvantages and shortcomings as described above and taking the prior art as discussed into account, an object of the present invention is to overcome the above-mentioned problems that earlier tanks and earlier methods have experienced.

This object is accomplished by an onboard fuel tank comprising the features of claim 1 as well as by a method comprising the features of claim 15. Advantageous embodiments and expedient improvements of the present invention are disclosed in the dependent claims.

The present invention thus provides improvements for vehicle onboard fuel tanks, in particular for liquefied natural gas (LNG) vehicle onboard fuel tanks, and for methods for filling such tanks. In particular, the present invention provides an improved onboard fuel tank design that overcomes the disadvantages associated with onboard fuel tanks known from the prior art. More particularly, the present invention provides an onboard fuel tank that has an inner vessel design that restricts movement of liquid in the onboard fuel tank.

The design of the interior space of the tank employs

- at least one, in particular internal, baffle that can be vertical, horizontal or both, and/or
- at least one compartment that can be vertical, horizontal or both, and/or
- at least one packing material or packing,
-- that can be structured or random, and/or
-- that can be vertical, horizontal or both, or
- combinations of any of these components.

Further, the onboard fuel tank of the present invention is fixed within the vehicle at an appropriate non-vanishing angle to obtain maximum withdrawal of the LNG for the fuelling process.

In addition, the present invention may preferably utilize piping that provides a pressure raising circuit to either feel at least one, for example small, heat exchanger preferably designed to be

external or to be integral with the onboard fuel tank, in particular to be integrally attached at the fill entrance to the tank.

The cold temperatures obtained from the pressure raising heat exchanger can expediently be used to cool engine coolant fluid.

In an advantageous manner, the piping for the onboard fuel tank of the present invention also may enable low-pressure drop top and bottom fill lines that can be used for a one hose filling operation or for a two hose filling operation.

According to a favoured embodiment of the present invention, at least one means to allow for emptying the onboard fuel tank may be provided. For example, this emptying means can be at least one drain.

Independently thereof or in combination therewith, a differential pressure (DP) gauge mounted locally to give the driver a local level indicator can be expediently added. This gauge can also provide a signal back to the cab. Such local level indication would prove very useful when filling.

The present invention may be preferably used for liquefied natural gas (LNG) powered vehicles but can also be useful for other types of cryogenic tanks on board vehicles, such as those used for fuel purposes or for refrigeration purposes.

Brief description of the drawings

For a more complete understanding of the present inventive embodiment disclosures and as already discussed above, there are several options to embody as well as to improve the teaching of the present invention in an advantageous manner. To this aim, the present invention is described in more detail below; in particular, reference may be made to the claims dependent on claim 1; further improvements, features and advantages of the present invention are explained below in more detail with reference to preferred embodiments by way of non-limiting example and to the accompanying drawing taken at least partly in connection with the following description of the embodiments, of which:

Fig. 1 is a schematic diagram of an embodiment of a liquefied natural gas (LNG) vehicle onboard fuel tank according to the present invention, working according to the method of the present invention.

Detailed description of the drawings;

best way of embodying the present invention

As shown in Fig. 1, the present invention provides an onboard fuel tank 10 that may include baffles 20, packing 30 and compartments (not shown). Fig. 1 also shows that the onboard fuel tank 10 can be filled using either or both of two fill hoses 50, 55 and an integral or external heat exchanger 60. This reduces the cost and complexity of the liquefied natural gas (LNG) filling operation significantly.

The fill system operates in the following manner:

Liquefied natural gas (LNG) from the supply chain provides cold LNG to the bulk tank at about thirty psig (about 207 kPa). The onboard tank 10 requires liquid at about hundred psig (about 690 kPa). As noted, it is not feasible to simply add pressure to the onboard tank 10 because as the vehicle moves the cold LNG sloshes around and contacts the vapor phase causing the LNG to condense.

This results in a rapid pressure drop and the pressure raising circuit for the onboard tank 10, which is relatively small, becomes overworked. This is because a lot of heat is required to get the LNG to the required hundred psig (about 690 kPa) and to maintain the LNG at that pressure.

For example, heat inleak to the onboard tank 10 will raise the pressure by about thirty psig (about 207 kPa) per day. Therefore, if the onboard tank 10 were filled with thirty psig (about 207 kPa) conditioned liquid, it would typically take about two days before the necessary pressure for operation would be reached and before the vehicle could run in LNG mode.

The baffles 20 and packing 30 used in the onboard tank 10 of the present invention stop the liquid from sloshing within the onboard tank 10 and therefore from contacting the gas phase. This allows the standard pressure raising circuit for the onboard tank to work properly and to maintain the onboard tank at the needed pressure.

Further advantages can be achieved by the present invention with only very slight piping changes that allow for the fitting of some useful features:

A drain can be added so that the tank can be emptied. This is not a feature of current LNG onboard tanks, but one that could be very useful.

Further, a differential pressure (DP) gauge mounted locally to give the driver a local level indicator can be added. This device could also provide a signal back to the cab. This is easier to

maintain than the currently employed capacitance probe, and local level indication would prove very useful when filling.

The present invention provides many advantages over onboard fuel tanks known in the prior art. In particular, by including the baffles 20, compartments, packing 30 or combinations thereof, liquid movement within the onboard fuel tank 10 is reduced and therefore kinetic energy input is also reduced. This reduces the interaction between cold liquid and the vapor space that results in less vapor collapse and thus less pressure decrease that can be caused by vehicle movement.

By reducing the pressure decrease in the onboard fuel tank 10 that can be caused by vehicle movement, a small heat exchanger 60 can be incorporated into the design that can serve to maintain the onboard fuel tank pressure above the critical supply threshold pressure.

This allows the onboard fuel tank 10 to effectively function with any temperature of LNG and allows the onboard fuel tank 10 to be fueled with cold LNG. This in turn increases the capacity of the onboard fuel tank 10 and therefore the vehicle range while also removing the need to condition the LNG during the fuelling process.

By enabling a low pressure drop top and bottom fill option according to the present invention, a one or two hose filling method can be employed. This results in a lower pressure drop through the supply system, and therefore a lower supply pressure is required. This in turn reduces the costs of constructing, maintaining and operating the supply system.

By angling the onboard fuel tank 10 according to the present invention, the maximum possible withdrawal of LNG is enabled. This allows the vehicle to use all of the LNG in the onboard fuel tank 10 again increasing range of the vehicle and enabling the maximum possible vehicle usage of the LNG.

While described with respect to liquefied natural gas (LNG) vehicle onboard fuel tanks 10, the present invention is also useful for other types of cryogenic tanks on board vehicles, such as those used for fuel purposes or for refrigeration purposes.

In addition, modifications to the piping connections into or out of the onboard fuel tank 10 are possible. For example, the flow of liquid product may use a lute or thermosyphon, essentially a U-bend type liquid seal to prevent gas flow, to enable automatic use of gaseous product over liquid when there is excess pressure in the onboard fuel tank 10. Additional control elements, such as a combined pressure raising/economizer regulator could be added to the system for operational improvements.

Further advantages can also be realized by the present invention. For example, the cold temperatures obtained from the pressure raising heat exchanger 60 can be used to cool engine coolant fluid.

The low pressure drop capability would enable prior art LNG supply methods to better recover the high pressure in the onboard fuel tank 10 as the bulk LNG tank could run at lower pressures or at the same pressure, with recovered gas being returned to the bulk tank. The low pressure drop capability would also enable prior art LNG supply methods to fill more quickly and thus save operation time.

In addition, the low pressure drop capability of the present invention would enable prior art LNG supply systems to reduce the operating pressure and thus reduce costs. In particular, bulk LNG storage tanks could operate at lower pressures and therefore thinner wall vessels could be used to save equipment costs. Pumps associated with the system would require a lower discharge head and therefore be made simpler with fewer stages and increased flow rates, thereby saving costs and operational time.

The ability to use LNG at any condition in the bulk tank removes the requirement for controlling the condition of the LNG in the bulk tank, thereby simplifying station design and saving design, capital and operation costs.

It will be understood that the embodiments described herein are merely exemplary and that one skilled in the art may make variations and modifications without departing from the spirit and scope of the present invention. All such variations and modifications are intended to be included within the scope of the present invention as described above. Further, all embodiments disclosed are not necessarily in the alternative, as various embodiments of the present invention may be combined to provide the desired result.

List of reference numerals

10 onboard fuel tank
20 baffle
30 packing or packing material
50 first means for hose filling, in particular first fill hose
55 second means for hose filling, in particular second fill hose
60 heat exchanger

Claims

1. An onboard fuel tank (10) wherein the interior space of the onboard fuel tank (10) includes at least one of baffles (20), packing material (30) or compartments and wherein the onboard fuel tank (10) is arranged to be mounted at an angle within a vehicle.

2. The onboard fuel tank according to claim 1 wherein the baffles (20) are arranged vertically, horizontally or both.

3. The onboard fuel tank according to claim 1 or 2 wherein the packing material (30) is arranged vertically, horizontally or both.

4. The onboard fuel tank according to at least one of claims 1 to 3 wherein the packing material (30) is structured packing or random packing.

5. The onboard fuel tank according to at least one of claims 1 to 4 wherein the compartments are arranged vertically, horizontally or both.

6. The onboard fuel tank according to at least one of claims 1 to 5 further including a heat exchanger (60), designed to be integral with the onboard fuel tank (10) or to be external.

7. The onboard fuel tank according to claim 6 wherein the integral heat exchanger (60) is integrally attached at the fill entrance to the onboard fuel tank (10).

8. The onboard fuel tank according to at least one of claims 1 to 7 further including at least one means (50, 55) to allow for single or dual hose filling.

9. The onboard fuel tank according to claim 8 wherein the means to allow
- for single hose filling is a fill hose (50 or 55) or
- for dual hose filling are two fill hoses (50, 55).

10. The onboard fuel tank according to at least one of claims 1 to 9 further including at least one means to allow for emptying the onboard fuel tank (10).

11. The onboard fuel tank according to claim 10 wherein the means to allow for emptying the onboard fuel tank (10) is at least one drain.

12. The onboard fuel tank according to at least one of claims 1 to 11 further including at least one local level indicator.

13. The onboard fuel tank according to claim 12 wherein the local level indicator is at least one differential pressure gauge.

14. The onboard fuel tank according to at least one of claims 1 to 13 wherein the vehicle is a liquefied natural gas (LNG) powered vehicle.

15. Method for filling an onboard fuel tank (10) according to at least one of claims 1 to 14 wherein the onboard fuel tank (10) is mounted at an angle within a vehicle.

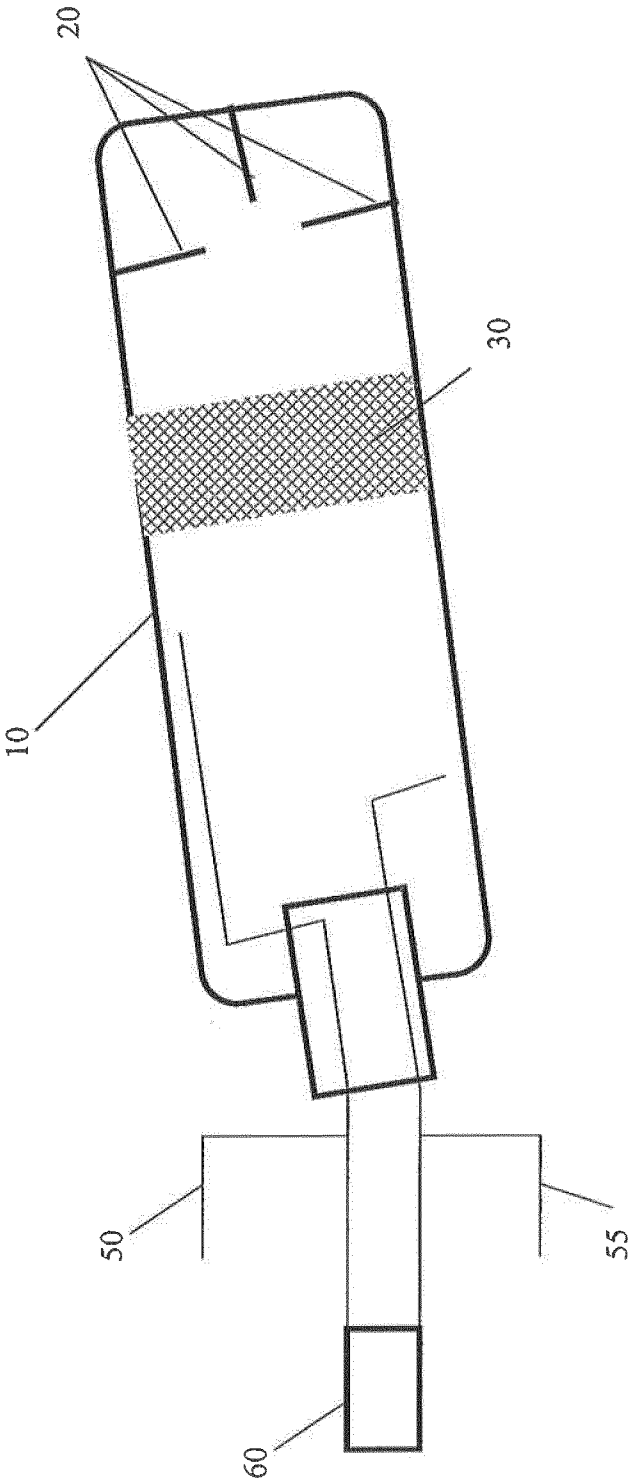


Fig. 1

INTERNATIONAL SEARCH REPORT

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A. CLASSIFICATION OF SUBJECT MATTER
INV. F17C1/08 F17C5/02 F17C13/08
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F17C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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Date of the actual completion of the international search	Date of mailing of the international search report
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Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Stängl, Gerhard

1

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