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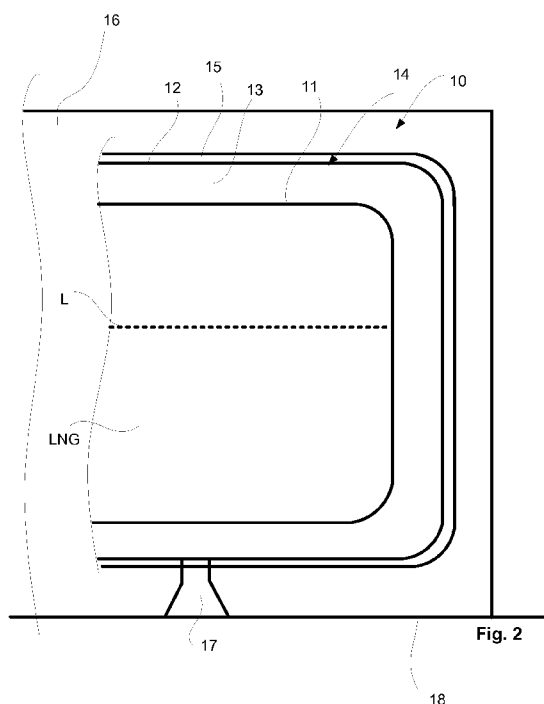
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(54) **Title:** LNG TANK



(57) **Abstract:** The invention relates to an LNG tank (10) located in a tank hold space (16) of a marine vessel comprising an inner metal shell (11), an outer metal shell (12) and an isolation space (13) between the shells (11, 12) advantageously containing vacuum, which LNG tank (10) further comprises an insulation material (15) adhered on outer surface (14) of the outer metal shell (12).

LNG tank

The invention is in general related to the field of storing liquid fuel, in particular liquefied natural gas (LNG), as a marine fuel in one or more engines of a ship
5 or of a corresponding sea-going vessel. In particular the invention is related to LNG tanks and connecting pipes to an LNG tank. More particularly the invention relates to the LNG tank according to the preamble of the independent LNG tank claim.

Liquid fuels that are used as marine fuels are typically liquefied natural gas,
10 liquefied petroleum gas or liquid petroleum gas (LPG), methanol, ethylene. Natural gas is in gaseous form in room temperature. In ships that use natural gas as fuel, the natural gas is typically stored onboard in liquid form, and thus this marine fuel is commonly called by its acronym LNG (Liquefied Natural Gas). Natural gas can be kept in liquid form by maintaining its temperature be-
15 low a boiling point, which is approximately -163 °C. LNG system onboard comprises typically a bunkering station, which is the ship's connection with a LNG terminal on shore or with an LNG bunkering barge, insulated pipes for leading LNG to an LNG tank, which is for storage of LNG and a tank connection space where LNG is controllably evaporated and its distribution to the en-
20 gine(s) is arranged. Typically LNG tank is a cylindrical, double-walled or single-walled, insulated stainless steel tank.

The LNG tank is usually the most expensive item in the LNG fuel handling system, taking up even 50-60% of the total cost of the system. For smaller tank sizes (below 300 m²) double-walled structure is typically used, with a vacuum
25 generated between the shells for heat insulation with possible perlite insulation. In double shell tanks the inner wall is stainless steel and the outer wall can be either stainless steel or carbon steel.

The natural gas is delivered to the engines as a gas but stored as a liquid. A tank room or a tank connection space is associated with a storage tank and
30 contains the equipment to convert the liquid into a gas for safe delivery to the engines. The tank room is also considered a 'secondary barrier' in case there should be leakage of the LNG, since liquid pipes and valves are inside it.

In patent application publication WO 2013/128063 is disclosed an LNG tank having an inner shell of stainless steel and an outer shell spaced at a distance from the inner shell, the said inner and outer shells defining an isolation space there between. The tank consists of a stainless steel inner shell, which is designed for an internal pressure, and an outer shell that acts as a secondary barrier. The outer shell can be made of either stainless steel or nickel steel. The tank is insulated with perlite/vacuum.

Natural gas is a safe fuel when the right precautions are taken. Neither is LNG in a liquid state explosive, corrosive or toxic. Thus, possible spillages will not cause any lasting contamination, as the liquid will evaporate as gas.

The low temperature, however, is an issue when considering normal marine vessel steels as too low temperatures may cause defects such as cracks to the steel. For example for some commonly used marine vessel structure steels the temperature is not allowed to drop below -5°C. A marine vessel refers to a ship, or other floating structure, such as an off-shore structure.

One important problem to be solved relates to the scenario of loss of vacuum in double shelled storage tanks. In case of loss of vacuum the insulation properties will be significantly reduced, which causes the temperature of the outer shell to drastically decrease. A reduced temperature on the outer shell will conduct coldness to the surrounding walls of a tank hold space and to other surrounding structures of the marine vessel. A tank hold refers to a compartment inside the marine vessel hull that surrounds the LNG tank and the tank connection space. In case the surrounding structures are not constructed of a cold resistant material such as stainless steel, which is expensive, the problem is to be solved so that the temperature of the surrounding structures will not reach the temperature limitations of the material. According to the worst case scenario the leakage scenario shall be calculated with a -163°C outer shell temperature. These problems enhance especially in cases where the LNG tank is located in a tank hold space of a marine vessel.

An object of the present invention is to provide an improved LNG tank, in which the problems described above are eliminated or at least minimized.

Another object of the invention is to prevent any leakage and cold temperatures related problems in connection with an LNG tank.

Another object of the invention is to create a double-shell LNG tank with more LNG space within a certain space.

- 5 In order to achieve the above objects and those that will come apparent later the LNG tank according to the invention is characterized by the features of independent LNG tank claim. Advantageous embodiments and features are defined in dependent claims.

- 10 According to the invention the LNG tank located in a tank hold space of a marine vessel comprises a inner metal shell, an outer metal shell and an isolation space between the shells containing vacuum, where in the LNG tank further comprises an insulation material adhered on the outer surface of the outer metal shell.

According to an advantageous feature the insulation material adhered on the outer surface of the outer metal shell substantially covers the outer surface of the outer shell of the LNG tank.

- 15 According to an advantageous aspect the insulation material adhered on the outer surface of the outer metal shell is polyurethane (PUR) or other corresponding onto the outer surface of the outer shell of the LNG tank sprayed insulating foam. Advantageously thermal conductivity (NPT) of the PUR is: below $0.2 \text{ W/m} \cdot \text{K}$ and density is $110\text{--}130 \text{ kg/m}^3$.
- 20 According to another advantageous aspect the insulation material adhered on the outer surface of the outer metal shell is formed of at least one insulation panel, advantageously several insulation panels, substantially covering the outer surface of the outer shell of the LNG tank. Advantageously the insulation material adhered on the outer surface of the outer metal shell is formed of
- 25 several insulation panels forming a substantially continuous insulation material layer onto the outer surface of the outer shell of the LNG tank.

- According to another advantageous aspect the insulation material adhered on the outer surface of the outer metal shell comprises at least one insulation panel and polyurethane (PUR) or other corresponding onto the outer surface
- 30 of the outer shell of the LNG tank sprayed insulating foam.

According to an advantageous feature the isolation space between the inner metal shell and the outer metal shell containing vacuum is perlite filled.

According to an advantageous feature the inner metal shell is stainless steel and the outer metal shell is stainless steel.

- 5 According to an advantageous feature the insulation panels are vacuum insulated panels (VIP) comprising vacuum inside a reflective layer. By the vacuum an effective form of insulation is achieved and thus the required insulation thickness can be minimized with the use of VIPs. The VIPs can be of different shapes and are mounted on the outside of the outer shell. Advantageously thermal conductivity (NPT) of the VIPs is: below $0.0023 \text{ W/m} \cdot \text{K}$ and density is $270 - 290 \text{ kg/m}^3$.

- 10 According to an advantageous feature the isolation space between the tank shells is $250 - 350 \text{ mm}$ thick, and comprises vacuum filled with perlite. The insulation thickness of the insulation material formed of vacuum insulated panels adhered on the outer surface of the outer shell of the LNG tank is $30-70 \text{ mm}$.

- 15 According to an advantageous feature surrounding structures of the LNG tank comprise at least one wall or floor of a tank connection space i.e. a tank room and the material of the surrounding structure is DNV grade A steel (NV A steel).

According to an advantageous aspect a marine vessel comprises an LNG tank according to the invention.

- 20 As the LNG tank comprises the insulation of the outer shell surface, in the case of loss or reduction of vacuum from the isolation space between the shells of the LNG tank, the insulation prevents the reduced temperature on the outer shell to conduct coldness to the surrounding structures and thus the temperatures of the surrounding structures remain within the temperature limitations of the material even in the worst case scenario with a -163°C outer shell temperature of the LNG tank.
- 25

The insulation of the outer shell surface of the LNG tank also reduces the requirement of the distance between the shells as the outer insulation decreases capacity needed of the isolation space between the shells.

- 30 The insulation of the outer shell surface of the LNG tank also makes it possible to reduce the distance from the outer surface of the tank to the walls of the

tank room due to the improved insulation achieved by the insulation of the outer shell surface.

As the problem relating to cold convection in case of loss or significant loss of vacuum of the isolation space between the shells of the LNG tank is solved by insulation of the outer surface of the outer shell of the LNG tank also a clear advantage in respect of space requirements is achieved. In ships and other marine application the space is extremely limited the solution according to the advantageous feature of the invention to use as the insulation material the vacuum insulation panes is very advantageous as the vacuum insulation panels are space effective.

In the following the invention is described in more detail by reference to the accompanying drawing in which

Fig. 1 shows schematically a prior art LNG fuel distribution architecture and

Figs 2 - 3 show schematically an advantageous example of the invention.

Fig. 1 illustrates schematically the architecture of a known system onboard an LNG-fuelled ship. An LNG bunkering station 101 is located on the deck and used to fill up the system with LNG. The LNG fuel storage system comprises one or more thermally insulated gas tanks 102 for storing the LNG in liquid form, and the so-called tank room 103 where the LNG is controllably evaporated and its distribution to the engine(s) is arranged. The LNG tank 102 and the tank room 103 are located in a tank hold space 16 of a marine vessel. Evaporation means a phase change from liquid to gaseous phase, for which reason all subsequent stages should leave the L for liquefied out of the acronym and use only NG (Natural Gas) instead.

The engine 104 or engines of the ship are located in an engine room 105. Each engine has its respective engine-specific fuel input subsystem 106, which in the case of gaseous fuel is in some sources referred to as the GVV (Gas Valve Unit). The tank room 103 of fig. 1 comprises two evaporators, of which the first evaporator 107 is the so-called PBU (Pressure Build-Up) evaporator used to maintain a sufficient pressure inside the gas tank 102. Hydrostatic pressure at the inlet of a main supply line 108 inside the gas tank 102 is the driving force that makes the LNG flow into the second evaporator 109, which is the MGE or Main Gas Evaporator from which the fuel is distributed in gaseous

form towards the engines. In order to ensure that evaporated gas flows to the GVU(s) and further to the engine(s) at sufficiently high pressure, the PBU system maintains the internal pressure of the gas tank 102 at or close to a predetermined value, which is typically between 5 and 7 bars.

- 5 The engine 104 comprises one or more cooling circuits. Schematically shown in fig. 1 is an external loop 110 of the so-called low temperature (LT) cooling circuit, which may be used for example to cool lubricating oil. The so-called LT water that circulates in the external loop 110 may have a temperature around 50 degrees centigrade when it goes through a heat exchanger 111, in which it
10 donates heat to a mixture of glycol and water that in turn transfers heat to the evaporators 107 and 109. The glycol / water mixture circuit comprises a circulation pump 112 and an expansion tank 113. Glycol is needed in the mixture to prevent it from freezing when it comes into contact with the extremely cold LNG inlet parts of the evaporators 107 and 109.
- 15 During the course of the following description of figures 2 – 3 corresponding reference numbers and signs will be used to identify corresponding elements, parts and part components unless otherwise mentioned. In the following the examples are described mainly by reference to an LNG tank of a ship or a corresponding marine vessel in view of simplifying the disclosure but it should be
20 noted that instead of this example any type of a tank for correspond liquid fuel tanks with similar problems for example cryogenic liquid tanks can have similar features and properties in accordance with the invention.

In the example of figures 2-3 schematic cross-sections of an LNG tank 10 located inside a tank hold space 16 of a marine vessel are shown. The LNG tank
25 10 is a double-shell LNG tank and comprises an inner shell 11 defining the tank space for the LNG and an outer shell 12. In the figure the level of the LNG is denoted by reference sign L. Between the inner shell 11 and the outer shell 12 the isolation space 13 is located. On the outer surface 14 of the outer shell 12 insulation material 15 is adhered. The insulation material 15 is advantageously VIP (vacuum insulated panels) and/or PUR (polyurethane). The insulation material 15 adhered on the outer surface 14 of the outer metal shell 12
30 substantially covers the outer surface 14 of the outer shell 12 of the LNG tank 10. The isolation space 13 between the inner metal shell 11 and the outer metal shell 12 advantageously contains vacuum. The isolation space 13 is advantageously perlite filled and it comprises 250 – 350 mm perlite. The insula-
35

tion thickness of the insulation material 15 in case formed of vacuum insulated panels adhered on the outer surface 14 of the outer shell 12 of the LNG tank 10 is 30-70 mm. The deck 18 below the LNG tank 10 located in a tank connection space i.e. a tank room is typically DNV grade A steel (NV A steel).

- 5 Above only some advantageous examples of the invention have been described to which the invention is not to be narrowly limited. It is clear to one skilled in the art that many modifications and variations are possible within the invention as defined in the following claims.

Reference signs used in figure 1

101 LNG bunkering station

102 tank

103 tank room

5 104 engine

105 engine room

106 fuel input subsystem

107 first evaporator

108 main supply line

10 109 second evaporator

110 external loop of the so-called low temperature (LT) cooling circuit

111 heat exchanger

112 circulation pump

113 expansion tank

15 114 tank hold space

Reference signs used in figures 2 - 3

10 LNG tank

11 inner shell

12 outer shell

20 13 isolation space

14 outer surface of the outer shell

15 insulation material

16 tank hold space

17 foot of LNG tank

18 deck

L level of LNG

5 LNG liquefied natural gas

Claims

1. LNG tank (10) located in a tank hold space (16) of a marine vessel comprising an inner metal shell (11), an outer metal shell (12) and an isolation space (13) between the shells (11, 12) advantageously containing vacuum, **characterized** in that the LNG tank (10) further comprises an insulation material (15) adhered on outer surface (14) of the outer metal shell (12).
5
2. LNG tank according to claim 1, **characterized** in that the insulation material (15) adhered on the outer surface (14) of the outer metal shell (12) substantially covers the outer surface (14) of the outer shell (12) of the LNG tank (10).
10
3. LNG tank according to claim 1 or 2, **characterized** in that the insulation material (15) adhered on the outer surface (14) of the outer metal shell (12) is polyurethane (PUR) or other corresponding onto the outer surface (14) of the outer shell (12) of the LNG tank (10) sprayed insulating foam.
15
4. LNG tank according to claims 1 or 2, **characterized** in that the insulation material (15) adhered on the outer surface (14) of the outer metal shell (12) is formed of at least one insulation panel containing vacuum, in particular formed of at least one vacuum insulation panel (VIP).
20
5. LNG tank according to claims 1 or 2, **characterized** in that the insulation material (15) adhered on the outer surface (14) of the outer metal shell (12) is formed of several vacuum insulation panels (VIP) forming a substantially continuous insulation material layer onto the outer surface (14) of the outer shell (12) of the LNG tank (10).
25
6. LNG tank according to any of previous claims, **characterized** in that the insulation material (15) adhered on the outer surface (14) of the outer metal shell (12) comprises at least one vacuum insulation panel (VIP) and polyurethane (PUR).
30

7. LNG tank according to any of previous claims, **characterized** in that the isolation space (13) between the inner metal shell (11) and the outer metal shell (12) contains vacuum and is perlite filled.
- 5 8. LNG tank according to any of previous claims, **characterized** in that the isolation space between the inner metal shell (11) and the outer metal shell (12) is 250 – 350 mm thick, and comprises vacuum filled with perlite and that the insulation thickness of the insulation material (15) formed of at least one vacuum insulated panel adhered on the outer surface of the outer shell of the LNG tank is 30-70 mm.
- 10
9. LNG tank according to any of previous claims, **characterized** in that surrounding structures of the LNG tank (10) comprise at least one wall or deck of a tank connection space i.e. a tank room and that material of the surrounding structure is DNV grade A steel (NV A steel).
- 15
10. A marine vessel comprising an LNG tank according to any of the previous claims.

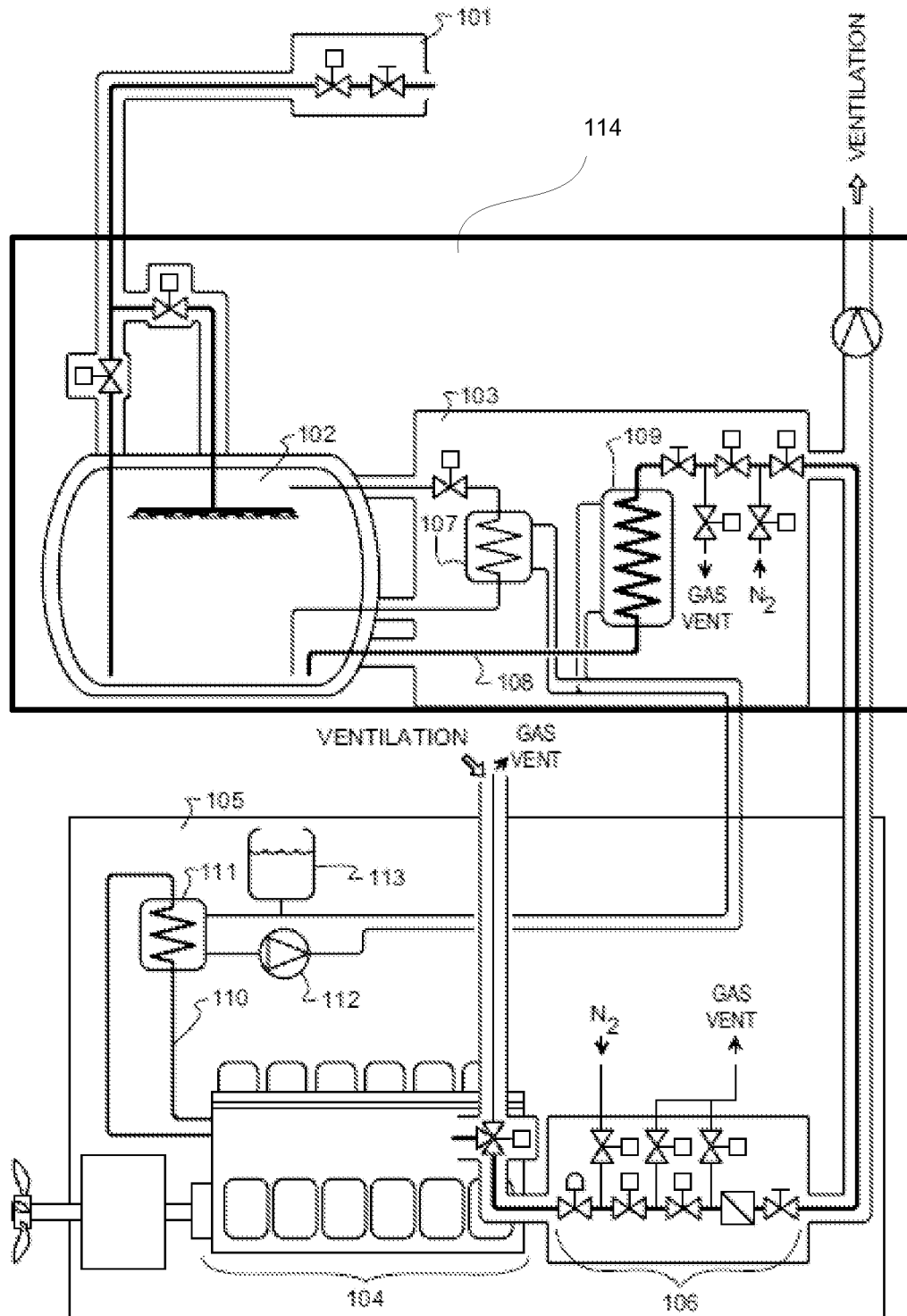


Fig. 1
PRIOR ART

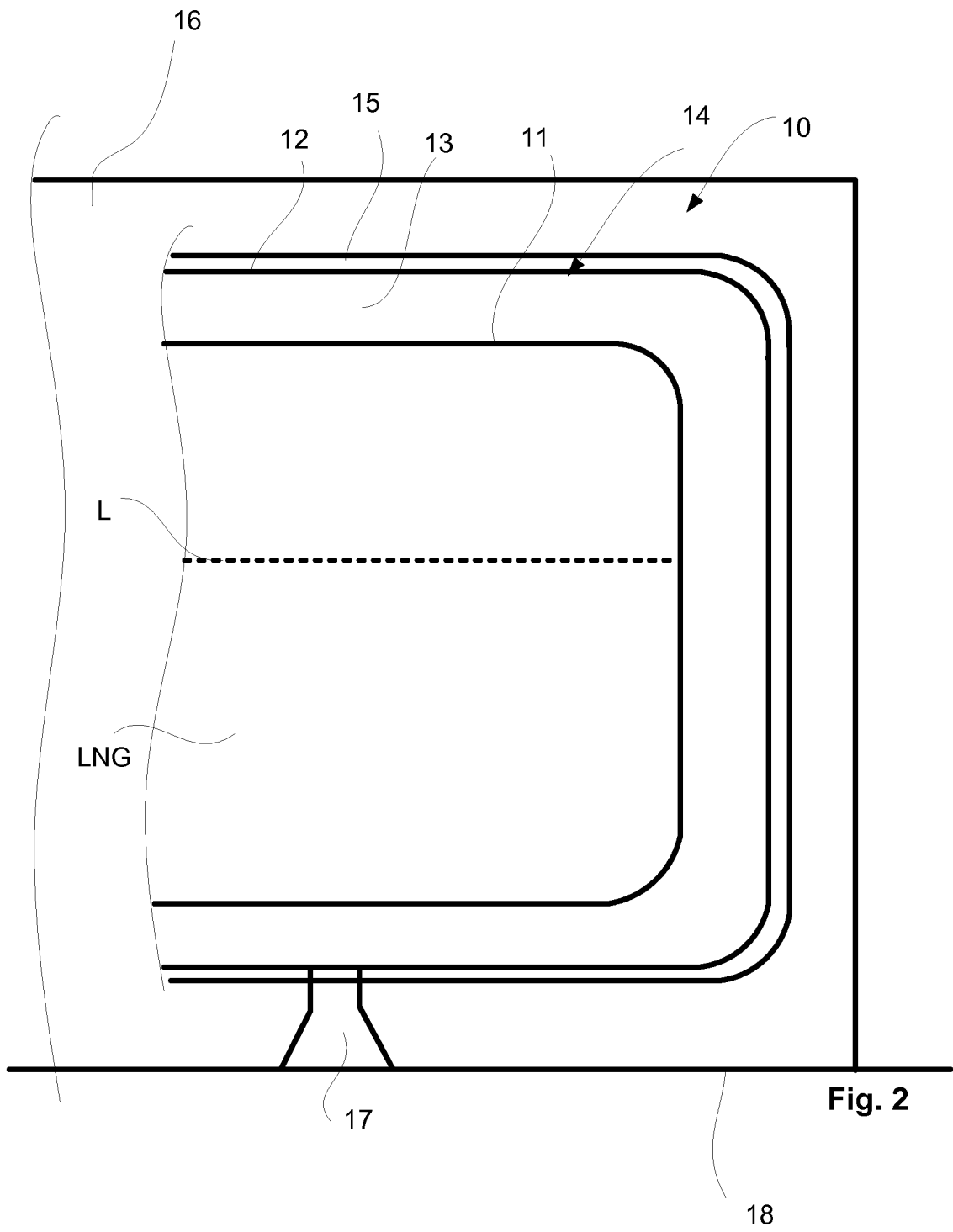


Fig. 2

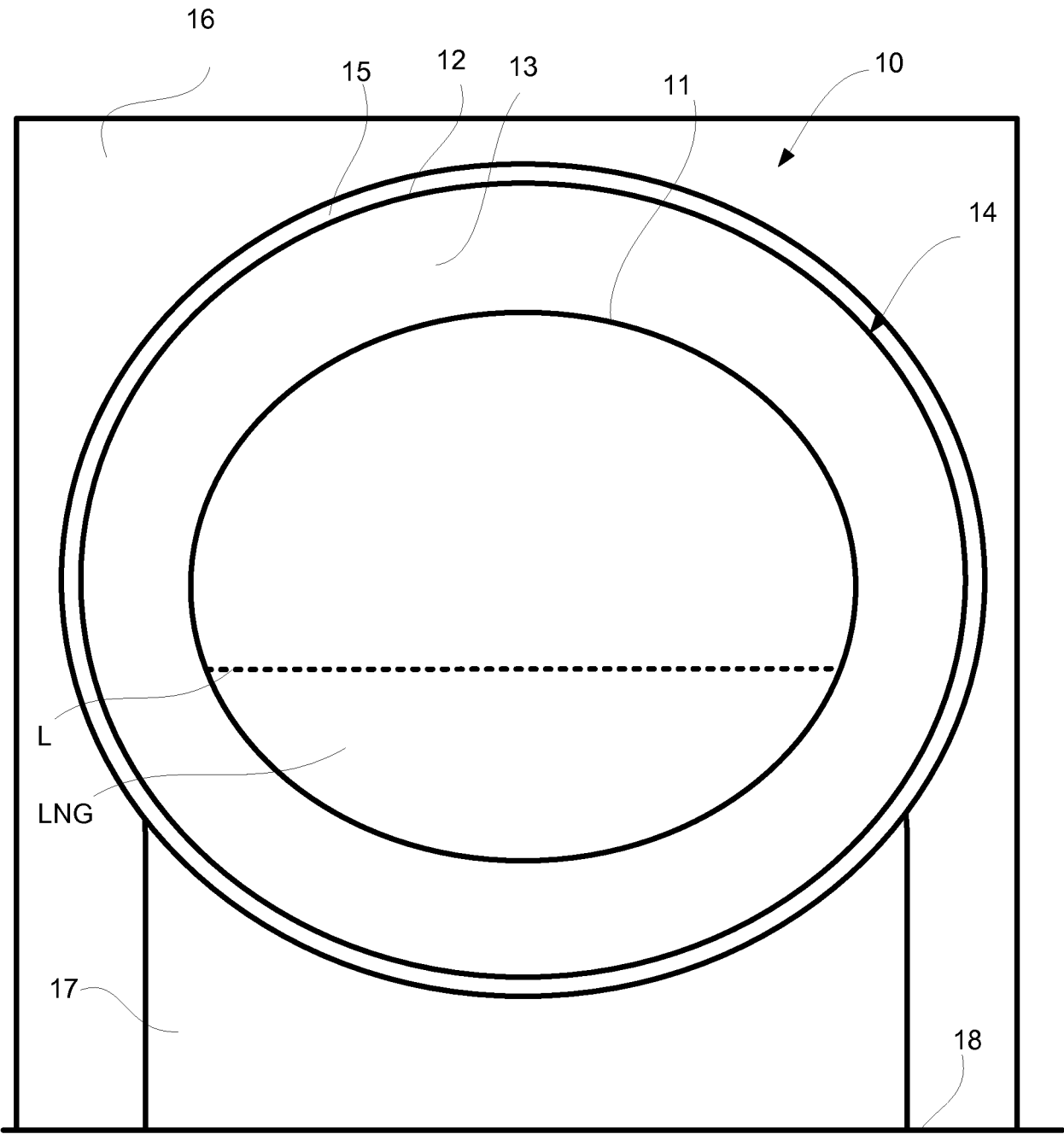


Fig. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/FI2014/051012

A. CLASSIFICATION OF SUBJECT MATTER
INV. F17C3/02 F17C3/04
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)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 440 031 A1 (NISSHIN SPINNING [JP]) 7 August 1991 (1991-08-07) page 1, line 12; figures 1,2 page 1, line 37 - page 2, line 23 -----	1-10
X	WO 2014/127840 A1 (BERGHOFF OLAF [DE]) 28 August 2014 (2014-08-28) page 1; figures 1-10 page 4, line 16 - line 20 page 5, line 23 pages 6-11 -----	1-10
X	FR 2 967 130 A1 (NEW GENERATION NATURAL GAS [FR]) 11 May 2012 (2012-05-11) abstract page 5, line 7 - line 8; figures 1-7 ----- -/--	1,2,4,5, 7-10



Further documents are listed in the continuation of Box C.



See patent family annex.

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"&" document member of the same patent family

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INTERNATIONAL SEARCH REPORT

International application No

PCT/FI2014/051012

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
E	WO 2014/203530 A1 (KAWASAKI HEAVY IND LTD [JP]) 24 December 2014 (2014-12-24) paragraph [0017] - paragraph [0032]; figures 1,2 -----	1-3,9,10

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/FI2014/051012

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0440031	A1	07-08-1991	DE 69105285 D1 12-01-1995
			EP 0440031 A1 07-08-1991
			JP H03208611 A 11-09-1991

WO 2014127840	A1	28-08-2014	NONE

FR 2967130	A1	11-05-2012	NONE

WO 2014203530	A1	24-12-2014	NONE
