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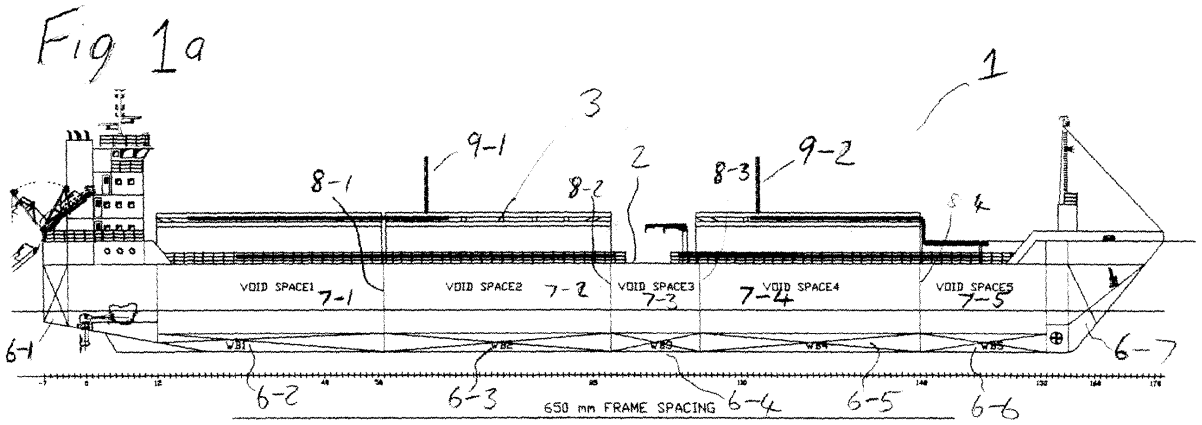
(71) Applicant: **RAM LNG Holdings Limited**
KY1-1108 Grand Cayman (KY)

(72) Inventor: **Newman, Michael**
Kilbrittain
County Cork (IE)

(74) Representative: **Skone James, Robert Edmund**
Gill Jennings & Every LLP
Broadgate House
7 Eldon Street
London EC2M 7LH (GB)

(54) **Vessel for transport of liquefied natural gas**

(57) A vessel for the transportation of liquefied natural gas comprising at least one cryogenic container (3-1) mounted to the open deck of the vessel and means (10) for transporting liquefied natural gas into or out of the cryogenic container.



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Description

[0001] The invention relates to a vessel for transport of liquefied natural gas (LNG).

The invention also relates to a method of adapting a vessel to make it suitable for the transportation of liquefied natural gas (LNG).

[0002] Liquefied natural gas (LNG) is natural gas cooled down to its boiling point temperature of approximately -160 °C at atmospheric pressure to reach cryogenic liquid condition. LNG is produced to enable the efficient storage and transport of natural gas. LNG is stored and transported in cryogenic containers. The LNG can be converted to natural gas by a process called regasification (vapourisation) and is typically used for fuel for domestic or industrial use and power generation.

[0003] A cryogenic container is a thermally-insulated container for storing or transporting liquefied gases at cryogenic temperatures and at pressure, generally atmospheric. Typically a cryogenic container includes an inner vessel for containing the cryogenic fluid e.g. LNG, and an outer vessel for insulating the cryogenic fluid from the environment. The inner vessel includes a superconductive layer comprising a material that is superconducting at the temperature of the cryogenic fluid. This superconductive layer forms a magnetic field around the cryogenic container that repels electromagnetic energy, including thermal energy from the environment, keeping the cryogenic fluid at low temperatures. Other cryogenic container systems are also available for the transport of LNG.

[0004] Natural gas, for export as LNG, is sourced from an offshore or onshore natural gas field, a coal mine, biogas facility or a diversion of flare-gas. The gas is delivered to a liquefaction plant (LNG plant) located on site or at the export port.

[0005] The marine transportation of LNG is growing in use today. Although Cabot first patented a barge to carry liquid gas in 1914 it wasn't until 1964 that the first purpose-built ship was used.

[0006] There are two traditional approaches to the marine transportation of LNG.

The first, and dominant, approach utilises purpose built vessels having hull structures specially designed for transportation of LNG. Typically such LNG vessels or tankers are double-hulled ships designed and insulated to prevent leakage or rupture. The LNG is stored in a special containment system within the inner hull of the vessel and can be generally described in either of two categories: independent tanks, generally self-supporting and constructed of aluminium alloy, and membrane tanks which rely entirely on the surrounding hull structure and are in intimate contact therewith.

[0007] The most common containment system for the transport of LNG is self-supporting spherical tanks constructed from aluminium. The spherical shape of such tanks enables stresses and fatigue life of the structure to be predicted with a high degree of accuracy. In order to effectively use the capacity of the hull the tanks are positioned half below and half above the deck. The protruding half of the tank is covered by a steel dome when in transit and typically four or five large tanks are placed in line in a ship. As half of the tank is located in the ship's hull, the hull must be specially designed in parts with high grade steel so as to prevent cracking should the contents of the tank escape which increases the cost of the structure.

[0008] An alternative to spherical tanks are prismatic tanks. Such tanks are also self-supporting and are shaped to follow the contours of the specially designed hull of the vessel and are located therein. Such free standing tanks make better use of the hull space than spherical tanks but it is harder to predict the effect of stress and fatigue because of their irregular shape.

[0009] An alternative to self-supporting structures are membrane systems which, use the inner wall of the hull as an integral part of the tank structure. Typically a membrane system will comprise an inner membrane wall defining the tank surrounded by an insulating layer to maintain the temperature of the tank contents. The insulation bears the load of the tank and is directly supported by the inner wall of the ship's hull. Thus, the space available inside the hull can be used to its full advantage. However, membrane tanks require materials that are more expensive than aluminium alloy for the inner wall of the tank. For example, the thin membrane wall may be made of the material Invar which has almost no thermal contraction and the insulation provided by way of plywood boxes filled with Perlite.

[0010] Common to both self-supporting and membrane systems is that the tanks are permanently fixed to the vessel and must be located at least partly in the ship hull for stability and to effectively utilise the hull capacity of the vessel. The majority of new vessels are for large capacity transportation of LNG, typically in the range of 120,000 m^3 - 140,000 m^3, but some more than 200000m^3. LNG carriers of this type are specially certified for carriage of LNG and dock at specialised LNG terminals for loading and unloading due to the large volumes, and associated safety risk, of LNG onboard. Such specially designed vessels have the disadvantage that they are potentially expensive and are only cost effective when transporting large volumes of LNG. Further, due to the large quantity of LNG they can only load or unload the LNG at specialised LNG terminals due to the strict safety requirements for dealing with such large volumes.

[0011] A second less common approach to the marine transport of LNG, is by way of freight or cargo transport. Herein the LNG is placed in an appropriate container, an ISO LNG cargo container or a trailer mounted LNG tank, at an LNG plant and transported to an export port by truck. Either the ISO container is transferred to a cargo ship or the truck and/or trailer is loaded onto the vessel. Typically, the ISO container is secured at the corners with locking devices. However LNG containing tanks are classified as 'dangerous goods' and typically can only be

stored on deck and not in the hull. Generally an area is designated on the deck for 'special' cargo and the LNG containing containers are stored there. This significantly reduces the flexibility of an operator to carry such containers. At the destination the containers are usually loaded and removed using cranes located at the port. The containers are then transported to the LNG storage facility by truck where the LNG is unloaded. The ISO containers are loaded and unloaded using cranes thus necessitating container port infrastructure to enable the LNG to be transported. In order to retrieve the LNG stored in the ISO containers or trailer mounted tanks the containers must first be unloaded from the ship and the LNG extracted at a specialised facility for this purpose.

[0012] Both of the traditional methods of transport demand a developed port infrastructure to enable safe docking and loading/unloading of the LNG. In many locations world-wide such port facilities do not exist.

[0013] In a first aspect according to the invention there is provided a vessel for the transportation of liquefied natural gas comprising at least one cryogenic container mounted to the open deck of the vessel and means for transporting liquefied natural gas into or out of the cryogenic container.

[0014] The vessel according to the invention is particularly advantageous as it can be manufactured at low cost because it does not require a specially adapted hull. Such a vessel is therefore particularly suitable for transporting smaller volumes of LNG. Further, by providing the cryogenic containers on the open deck the containers are made easily accessible and means such as a compressor or a pump for loading and unloading the LNG can be provided on the vessel itself, therefore, facilitating the transport of LNG to locations where little or no port infrastructure is in place. In addition, there is the opportunity to economically design and build suitable vessels that maximise the open deck area to enable greater volume of LNG to be transported using the proposed method.

[0015] The open deck area referred to herein is the deck of the hull and exposed to the outside, generally the main deck of the vessel. This main deck may need to be strengthened to support the cryogenic container(s) and auxiliary equipment.

[0016] In a further aspect of the present invention there is provided a method of modifying a vessel to make it suitable for the transportation of liquefied natural gas comprising, mounting at least one cryogenic container to the open deck of the vessel and providing the vessel with means for transporting liquefied natural gas into and out of the container. Utilising this method, existing vessels can, therefore, be retrofitted very easily without substantial modification of the original structure to incorporate the cryogenic containers and a means for loading and unloading the LNG to or from the containers.

[0017] Vessels having the LNG stored exclusively in cryogenic containers mounted on the open deck have the further advantage that the unused hull area may be utilised for the transport of other cargo. In addition, such vessels are safer than those known in the prior art because there is less danger of natural gas vapour becoming trapped in the hold where it could cause fire or explosion if accidentally ignited.

[0018] Embodiments according to the present invention will now be described with reference to the accompanying drawings, in which:-

Figure 1 a shows a schematic profile of a vessel in a first embodiment of the present invention;

Figure 1b shows a plan view of the vessel illustrated in Figure 1a;

Figure 2 shows a cross-section of the vessel of Figures 1 a and 1 b illustrating in particular the cross-sectional area of cryogenic containers mounted to the open deck; and

Figure 3 shows a schematic of apparatus suitable to be provided on the vessel of Figures 1 and 2 for loading and unloading LNG from the containers.

[0019] In an embodiment of the present invention the vessel comprises a ship 1 as illustrated in Figure 1 a. In this embodiment the ship has a length over all (LOA) of 124m and a length at the water line (LWL) of 118m, breadth 22.6m, depth 9.5m (to the main deck 2), draft (the distance from the bottom of the hull to the waterline) 4.0m and a volumetric displacement of about 8000t. The hull comprises a typical full form for seagoing ships with similar dimensions. The particulars of the mid ship section are vertical side, round bilge and flat bottom. As will be appreciated, other dimensions and designs of ship are possible depending on the cargo capacity and other performance requirements.

[0020] The general arrangement of the ship includes cargo storage 3 at the main deck 2, accommodation aft 4, machinery room 5, and ballast tanks 6-1 to 6-7 in double bottom, poop deck and forecastle. The compartments 7-1 to 7-5 under the main deck 2 in the cargo area 3 are void and are separated by watertight bulkheads 8-1 to 8-4. Access is arranged to the compartments 7-1 to 7-5 via the main deck.

[0021] The ship has permanent fresh water ballast in the double bottom ballast tanks 6-3, 6-4 and 6-5. The other tanks 6-2 and 6-3 and the aft and fore tanks 6-1 and 6-7 will utilize seawater and only be used when extra ballast is required. Cargo vents 9-1 and 9-2 extend vertically upwards from the cargo storage 3 to a height of 6m. The vents 9-1 and 9-1 are positioned horizontally at least 25m from the accommodation at the aft of the ship and from the forecastle respectively for safety reasons.

[0022] Figure 1b shows an overhead view of the ship of Figure 1 a. The vessel comprises 12 outsized cylindrical cryogenic containers 3-1 to 3-12 (24.5m long and 5.5m diameter) and ten standard 20' cylindrical ISO cry-

ogenic containers 3-13 to 3-22 mounted to the open deck. The distance between the edge of cargo containers 3-1, 3-5 and 3-9 and 3-4, 3-8 and 3-12 and the ship side is 800mm and the distance between cargo containers 3-1 to 3-22 is 500mm in order to provide access to the piping and valves of the containers. The outsized containers 3-1 to 3-12 are arranged in rows of four across the width of the main deck with their longitudinal axis parallel to that of the vessel whereas the ISO containers 3-13 to 3-22 are arranged in rows of five at the fore of the vessel. In this way the surface area of the main deck is utilised in an efficient manner.

[0023] A cargo loading and unloading area 10 is located on the main deck near midship. The loading and unloading area 10 preferably contains equipment including at least two cargo pumps (for pumping LNG to and from the containers), two cooling pumps, two compressors (for compressing natural gas vapour), two hose davits (mechanical arms for raising and lowering hose and other equipment onto the ship) and cargo manifold comprising an arrangement of valves and connections required to pump the LNG to and from the containers. As will be described in more detail below, the manifold is arranged so that each cargo pump can load or discharge LNG from each container.

[0024] Figure 2 shows a cross section of the ship shown in figures 1 a and 1b showing the ends of containers 3-1 to 3-4 in cross-section. The outsized containers are comprised of a stainless steel inner tank 3-1 a supported by a carbon steel outer vessel 3-1b. The container is hermetically sealed during transportation and comprises a multi-laminar insulating layer to prevent heating of the LNG stored therein. The containers 3-1 to 3-22 are preferably mounted to the surface of the vessel by mechanical s ea fastenings but any conventional fastening means or container locks known in the art for securing cargo to the surface of a marine vessel could be used. The fastener system chosen should be that that is best suited to the acceleration of the ship. As a further alternative the containers 3-1 to 3-22 may be permanently fixed to the deck of the ship by welding. The containers in this embodiment are designed for partial filling, and for 8bar internal pressure permitting approximately 40 days of storage without venting.

[0025] Figure 3 shows the details of the manifold and pump arrangement 10 located on the main deck of the ship and utilised to pump LNG to and from the containers 3-1 to 3-22. In the figure the ship manifold is shown connected to the lines of example container 3-1. As shown the manifold comprises two LNG transfer pumps 11 and 12 are fitted at main deck for LNG loading and discharging. The pumps are preferably horizontal centrifugal pumps suitable for cryogenic liquid transfer with a capacity of 300 m^3/h at 2.5 bar each. Two additional spray pumps 13 and 14 are provided that are operable to cool the system before starting of the cargo pumps 11 and 12 which are connected to the lines used for loading and discharging LNG.

[0026] The LNG container 3-1 is provided with a vapour line 3-1 c, vent line 3-1 d, liquid line (for carrying LNG) 3-1 e, a pressure gauge 3-1 f, level gauge 3-1g and two safety valves 3-1 h. This permits vapour generated during loading of the LNG containers 3-1 to 3-22 to be led back to onshore storage, for example, a truck. Further, it also permits vapour to be returned to the LNG containers 3-1 to 3-22 when unloading LNG. To assist in returning the vapour to the containers two multipurpose single stage compressors 15 and 16 are provided which are operable to increase the return vapour pressure as necessary. The LNG transfer lines 3-1 d, 3-1 e and 3-1f comprise pipes of stainless steel having thermal insulation to thermally isolate the pipes from the adjacent hull and container support structure. In addition a vaporizer 17 is provided that is operable for vaporising liquid LNG stored in the container into gaseous form. The vapourizer 17 essentially behaves as a compressor, increasing vapour pressure for offloading. It can be used to start the offloading process by taking some of the LNG and generating a vapour push back to the container thus aiding the unloading of the LNG. Then the compressors are picked up and the unloading is continued without further use of the vapourizer. When compressors are not available the vapourizer can be used in the unloading process. The LNG is intended to be carried at ambient pressure although at the end of a voyage the pressure will be increased slightly due to gas boil off.

[0027] The LNG transfer from the ship containers to the shore will be carried out by flexible hoses connected to main vent, vapour and liquid lines 18, 19 and 20 respectively. On completion of the LNG transfer, any LNG remaining in the deck lines and hoses can be drained by blowing the liquid into the ships with N_2 via blow line 21. For this purpose the vessel is preferably equipped with a suitable number of pressurised nitrogen containers (not shown).

[0028] Loading and unloading of the container 3-1 will now be described with reference to Figure 3. Considering, for example, the loading of the cryogenic containers utilising the pumps, the LNG enters the system via liquid line 30-1 and travels along liquid line 30-2 to line 30-3 and the pumps 11 and 12. From there it is pumped along liquid line 30-4 to line 20 and then to the cryogenic container via line 3-1 e. The vapour that is generated exits the container through line 3-1c to vapour line 19, and then to the vapour exit line 40-1 via line 40-3. Compressors 15 and 16 can be used to maintain the pressure in the system during this process.

[0029] Unloading utilising the pumps 11 and 12 comprises the LNG travelling along liquid lines 3-1 e from the container to liquid line 20. It is pumped by way of pumps 11 and 12 via line 30-3 from line 20 to line 30-1 via line 30-2 and to onshore storage. The vapour generated is beneficially used to keep the containers vapourized and enters the system from onshore via line 40-1. It travels through lines 40-3, vapour line 20 to line 3-1 c where it enters the cryogenic container.

[0030] Loading and unloading can also be accomplished utilising the compressors 15,16 only. Considering offloading utilising compressors 15 and 16, vaporised natural gas is taken from onshore though vapour lines 40-1 and 40-2. It then travels via line 40-3 to compressors 15 and 16 and from there to the container via lines 40-4, line 19 and line 3-1 c. For faster unloading and where available the vapour may travel via the vaporizer 17. The provision of vaporised natural gas to the cryogenic container pushes the LNG therein contained onshore via liquid lines 3-1 e, the stripping line and line 30-1.

[0031] Loading using compressors only, although not a preferred option, from a truck for example can be accomplished as follows, In this embodiment, the onboard compressors and onshore pumps are utilised. The vapour contained in the cryogenic container exits the container via lines 3-1 c and line 19 to enter the compressor line 40-3. Exiting via compressors 15 and 16, the vapour travels onshore through line 40-1. The LNG is transported onto the ship via line30-1 from onshore and to the cryogenic container via lines 20 and 3-1 e.

[0032] Ideally the system is cooled before loading or offloading through use of pumps 13 and 14 which should be connected to the loading/unloading lines. Alternately the system can be cooled through use of the compressors 15 and 16, provided the flow of vapour can be controlled, or a small vapourizer.

[0033] In a preferred embodiment the LNG is loaded from trucks using truck pumps and unloaded using the ship cargo pumps 11 and 12. Vapour generated in the system during the loading will be lead to the trucks and during unloading the vapour generated in the onshore storage will be lead back to the cryogenic containers onboard the vessel. This will keep the containers vapourized until they are loaded again. The compressors 15 and 16 are provided to increase vapour pressure if required.

[0034] Although in the above described embodiment the vessel is a cargo ship it will be appreciated that other types of marine vessel are possible. In particular, it is envisaged that the marine vessel could be a barge with the cryogenic containers and cargo manifold provided on the deck of the barge. A suitable tug boat could be used to transport the barge to a desired location for the loading or unloading of LNG.

[0035] In the above described embodiment the cargo manifold comprises cargo loading pumps 11 and 12, cooling pumps 13 and 14 and compressors 15 and 16. However, as will be appreciated other combinations of pumps and compressors could be provided depending on the transfer requirements and the facilities available onshore. In a yet further embodiment the manifold only comprises compressors 15 and 16 and LNG transfer is achieved with the assistance of onshore pumps in combination with the transfer means provided by compressors 15 and 16 on the vessel. Assuming onshore pumps are utilized at least one compressor and one small pump for cooling should be provided on the vessel. The number and size of compressors and pumps on the vessel dictates the speed of loading and unloading and is influenced by, amongst others, the onshore facilities available and the available deck space.

[0036] Although the above described embodiment comprises cylindrical cryogenic containers, containers of other shapes e.g. spherical, rectangular, square, prismatic etc, may be considered. Cylindrical cryogenic containers are preferred as they are the most efficient from a structural, volumetric and manufacturing standpoint.

[0037] In the above embodiment the cylindrical cryogenic containers are mounted with their longitudinal axis parallel to the longitudinal axis of the vessel. This provides the most efficient use of space in this embodiment. However the cryogenic tanks may be provided in any orientation e.g. they may be mounted with their longitudinal axis at right angles to the longitudinal axis. The preferred orientation of containers will be such that maximises storage of LNG on the open deck area.

[0038] The cryogenic containers are mounted on the open deck of the vessel in the embodiment described herein. The containers may however be provided with a steel framework that permits the containers to be stacked on top of each other.

Claims

1. A vessel for the transportation of liquefied natural gas comprising at least one cryogenic container mounted to the open deck of the vessel and means for transporting liquefied natural gas into or out of the cryogenic container.

2. A vessel according to claim 1 wherein said means comprises a pump operable to pump liquid natural gas into or out of the container.

3. A vessel according to any preceding claim wherein said means comprises a compressor operable to compress natural gas vapour.

4. A vessel according to any preceding claim wherein said cryogenic container is cylindrical.

5. A vessel according to any preceding claim wherein said container is mounted to the open deck by sea fastenings.

6. A vessel according to any of claims 1 to 4 wherein said container is mounted to the open deck by welding.

7. A vessel according to any preceding claim wherein said vessel is a ship.

8. A vessel according to claim 7 wherein said ship is a tanker or ferry.

9. A vessel according to any of claims 1 to 6 wherein said vessel is a barge.

10. A vessel according to any preceding claim wherein the one or more containers are mounted with their longitudinal axis parallel to the longitudinal axis of the vessel.

11. A vessel according to any preceding claim wherein the cryogenic containers are arranged such that they are accessible for maintenance.

12. A vessel according to at least claim 4 wherein the cylindrical containers comprise end caps.

13. A vessel according to any preceding claim wherein the cryogenic containers comprise steel, stainless steel or aluminium.

14. A method of modifying a vessel to make it suitable for the transportation of liquefied natural gas comprising:

mounting at least one cryogenic container to the open deck of the vessel; and
providing the vessel with means for transporting liquefied natural gas into and out of the container.

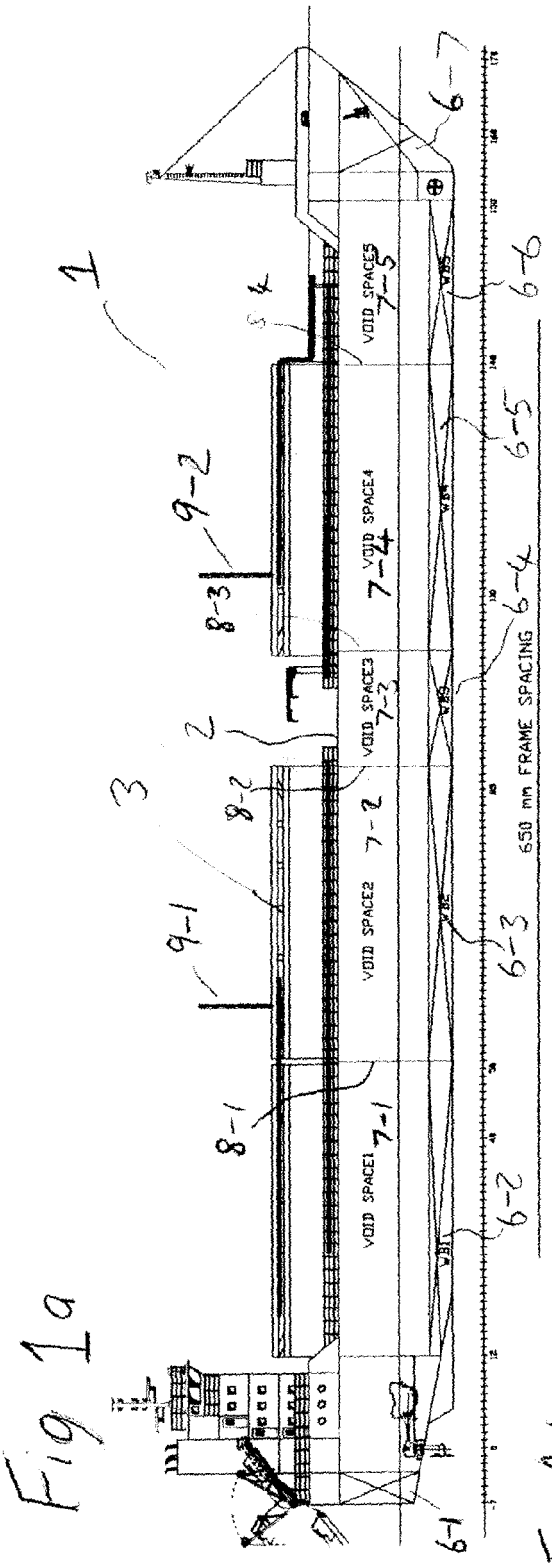

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6-4
6-5
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6-7
7-1
7-2
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7-4
7-5
8-1
8-2
8-3
9-1
9-2
VOID SPACE1
VOID SPACE2
VOID SPACE3
VOID SPACE4
VOID SPACE5
650 mm FRAME SPACING

Fig 1a

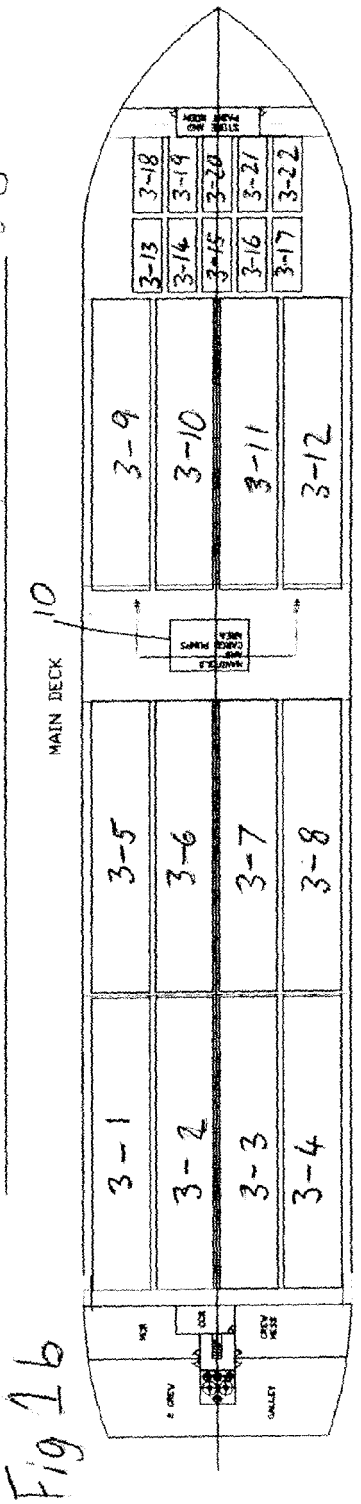

10
MAIN DECK
3-1
3-2
3-3
3-4
3-5
3-6
3-7
3-8
3-9
3-10
3-11
3-12
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3-19
3-20
3-21
3-22

Fig 1b

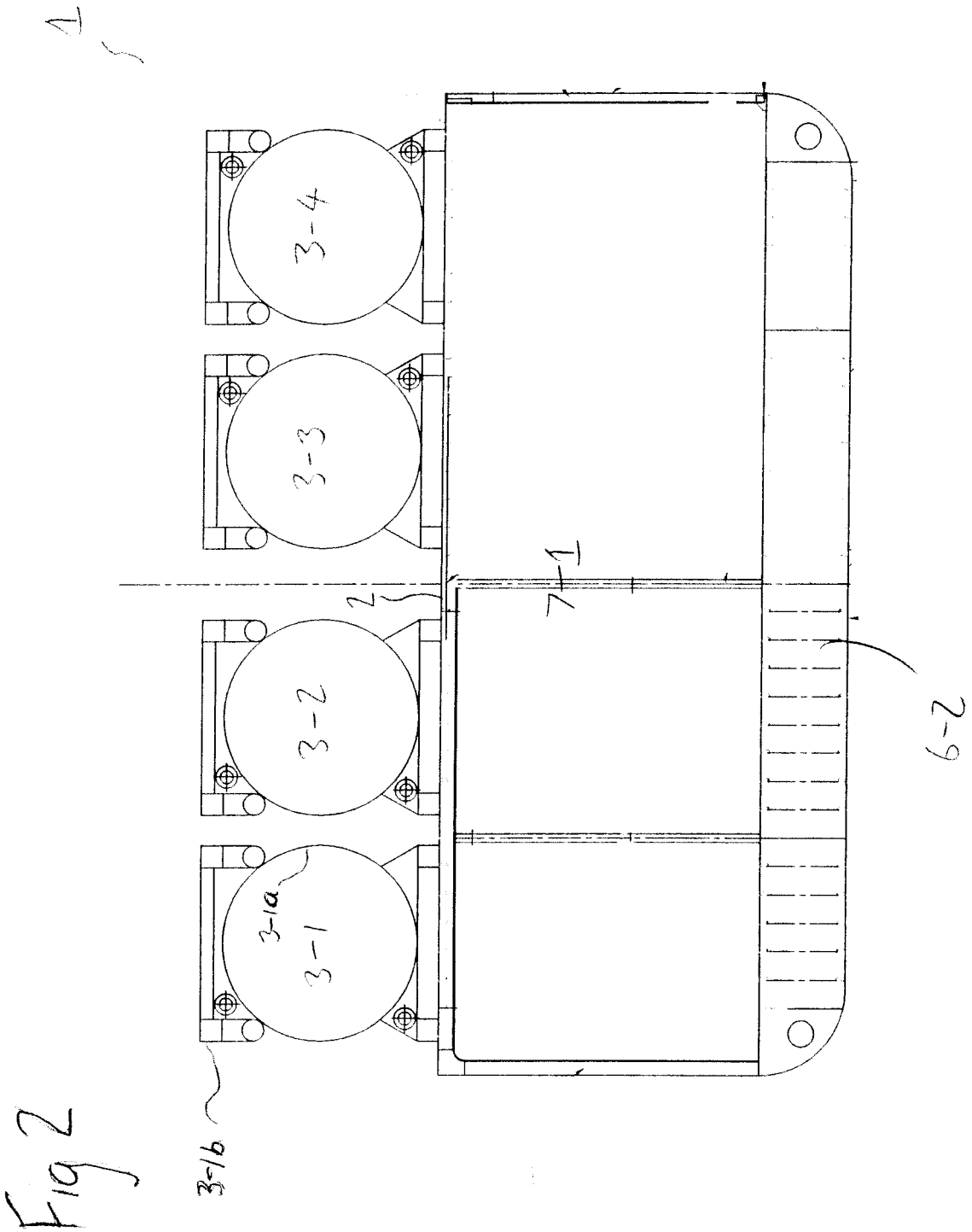


Fig 2

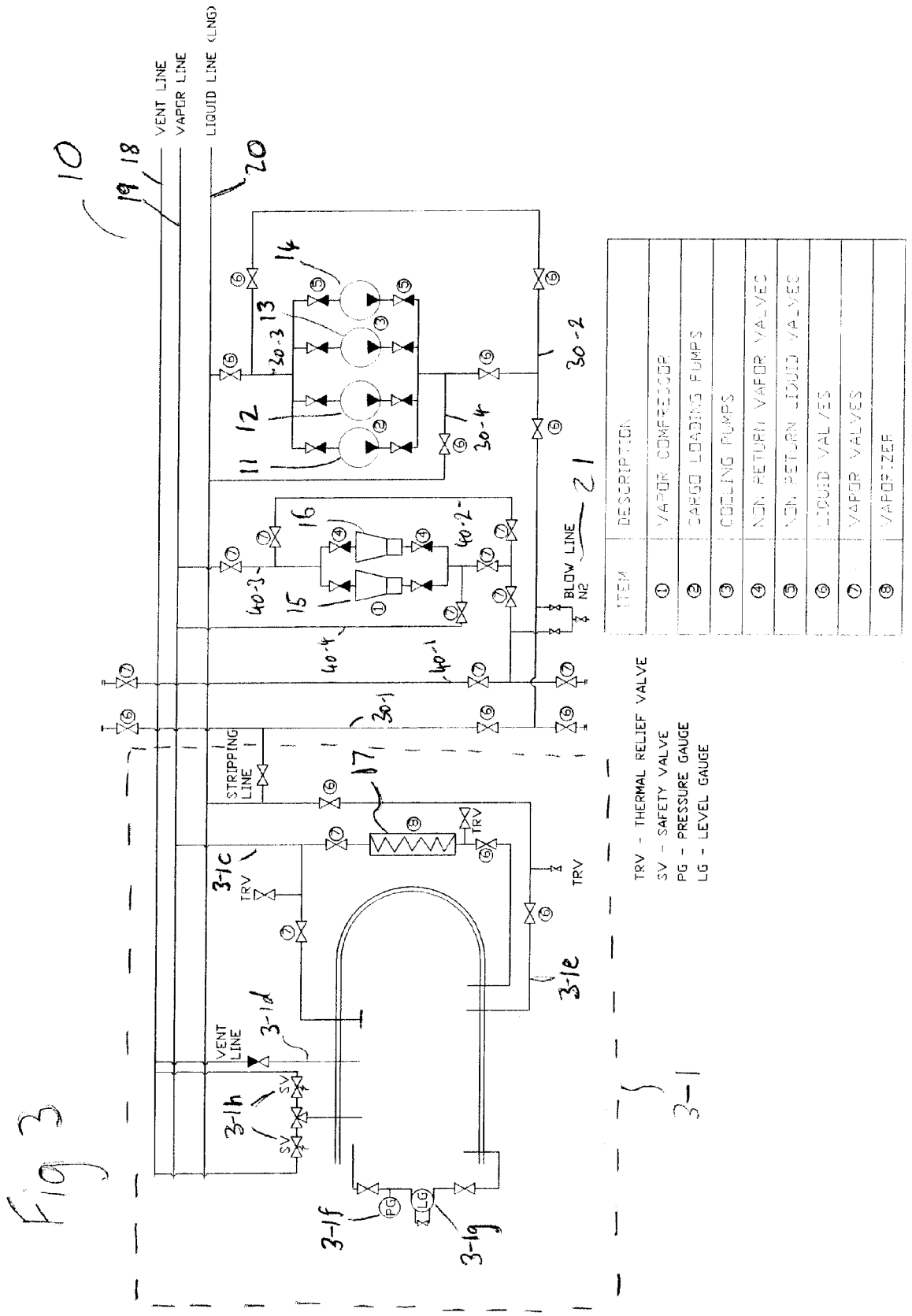

10
19
18
VENT LINE
VAPOR LINE
LIQUID LINE (LNG)
20
14
13
30-3
12
11
30-2
30-4
21
16
40-3
40-2
15
BLOW LINE
N2
40-4
40-1
30-1
17
STRIPPING LINE
TRV
3-1c
3-1e
3-1d
VENT LINE
SV
3-1h
3-1f
PG
LG
3-1g
3-1
TRV - THERMAL RELIEF VALVE
SV - SAFETY VALVE
PG - PRESSURE GAUGE
LG - LEVEL GAUGE
ITEM
DESCRIPTION
① VAPOR COMPRESSOR
② CARGO LOADING PUMPS
③ COOLING PUMPS
④ NON RETURN VAPOR VALVES
⑤ NON RETURN LIQUID VALVES
⑥ LIQUID VALVES
⑦ VAPOR VALVES
⑧ VAPORIZER

Fig 3

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EUROPEAN SEARCH REPORT

Application Number
EP 09 15 4599

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	2 September 2009	van Rooij, Michael

CATEGORY OF CITED DOCUMENTS

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 09 15 4599

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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