

【DESCRIPTION】**【Invention Title】**

SYSTEM AND METHOD FOR SUPPLYING LIQUEFIED GAS TO SHIP,
AND SYSTEM FOR SUPPLYING LIQUEFIED GAS FUEL TO SHIP

【Technical Field】

[1] The present invention relates to a liquefied gas supply system and method for vessels, which allows on-board treatment of boil-off gas generated upon supply of liquefied gas to a storage tank of a vessel without transferring the boil-off gas to an exterior.

[2] In addition, the present invention relates to a liquefied gas fuel supply system for vessels, which allows on-board treatment of boil-off gas generated upon supply of liquefied gas fuel to a fuel tank of a vessel without transferring the boil-off gas to an exterior.

【Background Art】

[3] In general, natural gas is transported to a gas terminal on land by an LNG carrier after being transformed into liquefied natural gas (LNG) through liquefaction at a production site.

[4] In a vessel, an empty LNG storage tank is generally filled with an inert gas to prevent gas explosion. That is, in test operation before navigation of the LNG carrier or before storage of LNG in the LNG storage tank of the LNG carrier, a gassing-up process of substituting the inactive gas in the tank with natural gas is performed.

[5] In addition, after the gassing-up process, a cooling-down process for reducing an internal temperature of the tank may be performed prior to supply of LNG to the tank.

[6] On the other hand, upon cooling down and supply of LNG, excessive boil-off gas (BOG) is generated and is generally transferred to a gas terminal to maintain the internal pressure of the tank.

[7] By way of example, about 4 to 7 MT/hr of BOG is generated in the

cooling-down process and about 7 to 9 MT/hr of BOG is generated in the LNG supply process. Upon supply of LNG, about 4 to 9 MT/hr of BOG is transferred from the vessel to the gas terminal in each stage and is recovered through reliquefaction or combusted in a gas combustion unit (GCU).

【Disclosure】

【Technical Problem】

[8] On the other hand, as countermeasures for addressing environmental problems, LNG bunkering vessels are actively used with increasing distribution of LNG fuel vessels. The LNG bunkering vessel refers to a vessel that supplies LNG to an LNG fuel vessel at sea after navigation to the LNG fuel vessel.

[9] Likewise, when LNG is supplied from the LNG bunkering vessel to the LNG fuel vessel, a large amount of boil-off gas is generated in the LNG fuel vessel to which LNG is supplied.

[10] Since it is difficult to install a pipe for recovering boil-off gas due to cargo in the LNG fuel vessel and the boil-off gas is a flammable material having a risk of fire or explosion, it is desirable that the boil-off gas generated upon supply of LNG be recovered from the LNG fuel vessel to the LNG bunkering vessel to be treated in the LNG bunkering vessel.

[11] Before supply of LNG fuel, an empty LNG fuel tank is generally filled with an inert gas in order to prevent gas explosion. That is, in test operation before navigation of the LNG fuel vessel or before supply of LNG fuel to the empty LNG fuel tank of the LNG fuel vessel, it is necessary to perform a gassing-up process for substituting the inactive gas in the tank with natural gas.

[12] In addition, after the gassing-up process, a cooling-down process for reducing an internal temperature of the fuel tank may be performed prior to supply of LNG to the fuel tank.

[13] On the other hand, upon cooling down and supply of LNG, excessive boil-off gas (BOG) is generated and is generally transferred to the gas terminal to maintain the internal pressure of the tank.

[14] Various techniques for supplying LNG fuel to the LNG fuel vessel using

such an LNG bunkering vessel at sea or for supplying LNG for test operation to various LNG vessels, for example, LNG carriers, provided with LNG storage tanks including an LNG fuel tank have been actively discussed in the art.

[15] As described above, in order to supply LNG to an empty LNG storage tank of the LNG carrier as a test operation target, the gassing-up process and the cooling-down process must first be performed. That is, in order to supply LNG for test operation to the LNG carrier using the LNG bunkering vessel, it is necessary for the LNG bunkering vessel to perform direct treatment of about 4 to 9 MT/hr of boil-off gas recovered from the LNG carrier in each stage.

[16] However, the LNG bunkering vessel has a restricted GCU capacity. In fact, LNG bunkering vessels, which adopt an LNG bunkering function and are built in Korea, and LNG bunkering vessels, which have been built by domestic shipbuilders and are operated in European ports, have a GCU capacity of less than 1 ton.

[17] In addition, since the LNG carrier in the test operation stage is not ready to operate the GCU or a reliquefaction apparatus capable of treating boil-off gas, it may be very difficult for the LNG carrier to process the boil-off gas.

[18] As such, in fact, it is very difficult to process all boil-off gas generated during cooling down and supply of LNG without venting the boil-off gas into the atmosphere.

[19] Therefore, the present invention is directed to solving the problems described above and embodiments of the present invention provide a liquefied gas supply system and method for vessels, which allow on-board treatment of boil-off gas generated upon supply of LNG to an LNG storage tank of an LNG carrier or upon supply of LNG for test operation thereto without recovering the boil-off gas to an LNG bunkering vessel.

[20] In addition, embodiments of the present invention provide a liquefied gas fuel supply system for vessels, which allows on-board treatment of boil-off gas generated upon supply of LNG to an LNG fuel tank of an LNG fuel vessel without recovering the boil-off gas to an LNG bunkering vessel.

【Technical Solution】

[21] In accordance with one aspect of the present invention, there is provided a system for supplying liquefied gas to ship adapted to supply liquefied gas from a liquefied gas supply vessel to a vessel including multiple liquefied gas storage tanks, the liquefied gas supply system including: a liquefied gas line along which the liquefied gas is supplied from the liquefied gas supply vessel to one of the multiple liquefied gas storage tanks; a gas discharge line along which boil-off gas generated in the one liquefied gas storage tank upon supply of the liquefied gas thereto is discharged; and a gas supply line along which the boil-off gas is supplied to one or more other liquefied gas storage tanks.

[22] Preferably, the liquefied gas supply system further includes a heater heating the boil-off gas discharged along the gas discharge line, wherein the boil-off gas heated by the heater is supplied to one or more other liquefied gas storage tanks along the gas supply line.

[23] Preferably, the boil-off gas generated in the one liquefied gas storage tank upon supply of the liquefied gas thereto is supplied to another liquefied gas storage tank.

[24] Preferably, the boil-off gas generated in the one liquefied gas storage tank upon supply of the liquefied gas thereto is supplied to all of the other liquefied gas storage tanks.

[25] Preferably, the liquefied gas line includes: a liquid crossover line connecting the liquefied gas supply vessel to the liquefied gas storage tanks and adapted to transfer the liquefied gas from the liquefied gas supply vessels; and a liquid line adapted to supply the liquefied gas to each of the liquefied gas storage tanks after division of the liquefied gas received through the liquid crossover line.

[26] Preferably, the liquid line further includes at least one shut-off valve blocking the liquid line to prevent the liquefied gas from being supplied to one or more other liquefied gas storage tanks upon supply of the liquefied gas along the liquid crossover line.

[27] Preferably, the shut-off valve is disposed between a point at which the liquid crossover line meets the liquid line and a point at which the liquid crossover line is branched off from the point at which the liquid crossover line meets the liquid

line to a liquefied gas storage tank that the liquid line first meets.

[28] In accordance with another aspect of the present invention, there is provided a method of supplying liquefied gas from a liquefied gas supply vessel to a vessel including multiple liquefied gas storage tanks, the method including: a liquefied gas supply step in which the liquefied gas is supplied from the liquefied gas supply vessel to one of the multiple liquefied gas storage tanks; a boil-off gas discharge step in which boil-off gas generated in the one liquefied gas storage tank upon supply of the liquefied gas thereto is discharged; and a gassing-up gas supply step in which the boil-off gas discharged from the one liquefied gas storage tank is supplied to one or more other liquefied gas storage tanks.

[29] Preferably, the boil-off gas discharged in the boil-off gas discharge step is heated and supplied to one or more other liquefied gas storage tanks.

[30] Preferably, the boil-off gas generated in the one liquefied gas storage tank upon supply of the liquefied gas thereto is discharged to another liquefied gas storage tank.

[31] Preferably, the boil-off gas generated in the one liquefied gas storage tank upon supply of the liquefied gas thereto is discharged to all of the other liquefied gas storage tanks.

[32] Preferably, the liquefied gas is blocked from being supplied to one or more other liquefied gas storage tanks upon supply of the liquefied gas to one of the liquefied gas storage tanks.

[33] In accordance with another aspect of the present invention, there is provided a method of supplying liquefied gas for test operation from a liquefied gas supply vessel to a liquefied gas carrier including multiple liquefied gas storage tanks, the method including: a cooling-down liquefied gas supply step in which the liquefied gas is supplied from the liquefied gas supply vessel to a cooling-down storage tank ready for a cooling-down process among the multiple liquefied gas storage tanks along a stripping line adapted to spray the liquefied gas to the liquefied gas storage tank; a cooling-down boil-off gas discharge step in which boil-off gas generated in the cooling-down storage tank upon supply of the liquefied gas thereto is discharged along a gas line adapted to discharge a gas from the liquefied gas

storage tank; and a first gassing-up gas supply step in which the boil-off gas discharged from the cooling-down storage tank is supplied to a first gassing-up storage tank ready for a gassing-up process among the multiple liquefied gas storage tanks.

[34] Preferably, the method further includes a first inert gas discharge step, in which an inert gas discharged from the first gassing-up storage tank by supplying the boil-off gas to the first gassing-up storage tank filled with the inert gas is supplied to a vent mast along a liquid line along which the liquefied gas is supplied to or discharged from the liquefied gas storage tank and along a second connection line connecting the liquid line to the vent mast.

[35] Preferably, the first gassing-up gas supply step further includes a boil-off gas treatment step in which the boil-off gas discharged from the cooling-down storage tank is compressed and heated before supply of the boil-off gas to the first gassing-up storage tank.

[36] Preferably, an amount of the boil-off gas discharged from the cooling-down storage tank is equal to or larger than an amount of boil-off gas for a gassing-up process for the first gassing-up storage tank, and the gassing-up process for the first gassing-up storage tank is finished upon completion of a cooling down process for the cooling-down storage tank.

[37] Preferably, the method further includes: a liquefied gas supply step in which, upon completion of the cooling down process for the cooling-down storage tank, with the cooling-down storage tank being ready for storage of the liquefied gas, the liquefied gas is supplied to a storage tank for supply ready for storage of the liquefied gas along a liquid line for storing the liquefied gas in the liquefied gas storage tank or for discharging the liquefied gas from the liquefied gas storage tank; a boil-off gas discharge step in which boil-off gas generated from the storage tank for supply upon supply of the liquefied gas to the storage tank for supply is discharged along the gas line; and a second gassing-up gas supply step in which the boil-off gas discharged in the boil-off gas discharge step is supplied to a second gassing-up storage tank ready for the gassing-up process among the multiple liquefied gas storage tanks.

[38] Preferably, the method further includes a second inert gas discharge step in which, with the second gassing-up storage tank filled with an inert gas, the inert gas discharged from the second gassing-up storage tank by supplying the boil-off gas to the second gassing-up storage tank is supplied to a vent master along the liquid line and a second connection line connecting the liquid line to the vent master.

[39] Preferably, the liquid line is connected to the storage tank for supply by a first liquid line; the liquid line is connected to the second gassing-up storage tank by a third liquid line; and a shut-off valve is disposed between a point at which the first liquid line is branched off from the liquid line and a point at which the third liquid line is branched off from the liquid line, the shut-off valve being closed in the second inert gas discharge step.

[40] Preferably, the second gassing-up gas supply step further includes a second boil-off gas treatment step in which the boil-off gas discharged from the storage tank for supply is compressed and heated before the boil-off gas is supplied to the second gassing-up storage tank.

[41] In accordance with a further aspect of the present invention, there is provided a system for supplying liquefied gas for test operation adapted to supply liquefied gas for test operation from a liquefied gas supply vessel to a liquefied gas carrier including multiple liquefied gas storage tanks, the system for supplying liquefied gas including: a stripping line adapted to spray the liquefied gas from the liquefied gas supply vessel to the liquefied gas storage tanks, a liquefied gas for cooling-down being transferred to a cooling-down storage tank among the multiple liquefied gas storage tanks along the stripping line; a liquid line adapted to supply the liquefied gas to the liquefied gas storage tanks or to discharge the liquefied gas therefrom, a liquefied gas for test operation being transferred to a storage tank for supply ready for storage of the liquefied gas along the liquid line after completion of cooling-down; and a gas line along which a gas is discharged from the liquefied gas storage tanks and along which boil-off gas generated in the cooling-down storage tank or in the storage tank for supply upon supply of the liquefied gas to the cooling-down storage tank or to the storage tank for supply is discharged, wherein the boil-off gas discharged from the cooling-down storage tank and the storage tank for

supply along the gas line is transferred to a gassing-up storage tank ready for gassing-up among the multiple liquefied gas storage tanks.

[42] Preferably, the liquefied gas supply system further includes a second connection line connecting the liquid line to a vent mast, wherein, the gassing-up storage tank is filled with an inert gas, the inert gas discharged from the gassing-up storage tank by supplying the boil-off gas to the gassing-up storage tank is transferred to the vent mast along the liquid line and the second connection line.

[43] Preferably, liquefied gas supply system further includes a supply liquid branch-off line connecting the liquid line to the cooling-down storage tank or the storage tank for supply; a gassing-up liquid branch-off line connecting the liquid line to the gassing-up storage tank; and a shut-off valve disposed between a point at which the supply liquid branch-off line is branched off from the liquid line and a point at which the gassing-up liquid branch-off line is branched off from the liquid line, the shut-off valve being adapted to block a path of the liquid line along which the liquefied gas flows to the cooling-down storage tank or the storage tank for supply from a path of the liquid line along which the inert gas discharged from the gassing-up storage tank flows through shut-off control.

[44] In accordance with yet another aspect of the present invention, there is provided system for supplying liquefied gas to ship adapted to supply liquefied gas from a liquefied gas supply vessel to a vessel including multiple liquefied gas storage tanks, the system for supplying liquefied gas including: a liquefied gas line along which the liquefied gas is supplied from the liquefied gas supply vessel to one of the multiple liquefied gas storage tanks; a gas supply line along which boil-off gas generated in the one liquefied gas storage tank upon supply of the liquefied gas thereto is discharged to one or more other liquefied gas storage tanks, wherein a gas discharged from the liquefied gas storage tank by supplying the boil-off gas to the liquefied gas storage tank is discharged along the liquefied gas line; and a shut-off valve provided to a portion of the liquefied gas line disposed between the liquefied gas storage tank to which the liquefied gas is supplied along the liquefied gas line and the liquefied gas storage tank to which the boil-off gas is supplied, the shut-off valve being adapted to block the liquefied gas flowing along the liquefied gas line

from mixing with the boil-off gas.

[45] Preferably, the liquefied gas supply system further includes: a manifold; and a crossover line connecting the manifold to the liquefied gas line, wherein the shut-off valve is a three-way valve disposed at a point at which the crossover line meets the liquefied gas line.

[46] Preferably, the liquefied gas supply system further includes: a heater heating the boil-off gas discharged along the gas discharge line, wherein the boil-off gas heated by the heater is supplied to one or more other liquefied gas storage tanks along the gas supply line.

[47] Preferably, the liquefied gas supply system s further includes: a connection line connecting the liquefied gas line to the vent mast, wherein the gas discharged from the liquefied gas storage tank to which the boil-off gas is supplied is an inert gas, the inert gas being transferred from the liquefied gas storage tank to the vent mast.

[48] In accordance with yet another aspect of the present invention, there is provided a method of supplying liquefied gas from a liquefied gas supply vessel to a vessel including multiple liquefied gas storage tanks, the method including: a liquefied gas supply step in which the liquefied gas is supplied from the liquefied gas supply vessel to one of the multiple liquefied gas storage tanks; a boil-off gas discharge step in which boil-off gas generated in the one liquefied gas storage tank upon supply of the liquefied gas thereto is discharged; a gassing-up gas supply step in which the boil-off gas discharged from the one liquefied gas storage tank is supplied to one or more other liquefied gas storage tanks; and an inert gas discharge step in which an inert gas filling the liquefied gas storage tank to which the boil-off gas is supplied is discharged when the liquefied gas storage tank receives the boil-off gas, wherein the inert gas is discharged along a liquefied gas supply line along which the liquefied gas is supplied to the liquefied gas storage tank.

[49] Preferably, the inert gas discharge step further include a shut-off step in which a portion of the liquefied gas supply line along which the liquefied gas flows to the liquefied gas storage tank is blocked from a portion of the liquefied gas supply line along which the inert gas flows.

[50] Preferably, the boil-off gas discharged in the boil-off gas discharge step is heated and supplied to one or more other liquefied gas storage tanks.

[51] In accordance with yet another aspect of the present invention, there is provided a test operation-system for supplying liquefied gas for ship adapted to supply a liquefied gas for test operation from a liquefied gas supply vessel to a liquefied gas carrier including multiple liquefied gas storage tanks, each of the multiple liquefied gas storage tanks being provided with a liquid branch-off line for transferring liquefied gas, a stripping branch-off line for spraying the liquefied gas, and a gas branch-off line for transferring boil-off gas, the multiple liquefied gas storage tanks being filled with an inert gas and including: a gassing-up storage tank in which a gassing-up process is performed; and a storage tank ready to receive liquefied gas after completion of the gassing-up process, the test operation-system for supplying liquefied gas including: a gas line connecting the gas branch-off lines to one another; a liquid line connecting the liquid branch-off lines to one another; and a shut-off valve controlling flow paths of the liquefied gas and the inert gas such that the liquefied gas is supplied from the liquefied gas supply vessel along the liquid branch-off line connected to the storage tank ready to receive the liquefied gas or along the stripping branch-off line while the boil-off gas discharged from the storage tank ready to receive the liquefied gas is transferred to the gassing-up storage tank along the gas line, and such that the inert gas filling the gassing-up storage tank is discharged along the liquid branch-off line provided to the gassing-up storage tank.

[52] Preferably, the test operation- liquefied gas supply system further includes a liquid crossover line connecting the liquid line to a manifold of the liquefied gas carrier, wherein the shut-off valve is a three-way valve disposed at a point at which the liquid line is connected to the liquid crossover line.

[53] Preferably, the shut-off valve is disposed between a point at which the liquid branch-off line of the storage tank ready to receive the liquefied gas is connected to the liquid line and a point at which the liquid branch-off line of the gassing-up storage tank is connected to the liquid line.

[54] Preferably, the gas line is provided with a compressor compressing the boil-

off gas and a heater heating the boil-off gas compressed by the compressor to allow the boil-off gas to be compressed and heated while being transferred from the storage tank ready to receive the liquefied gas to the gassing-up storage tank.

[55] Preferably, the storage tank ready to receive the liquefied gas includes: a cooling-down storage tank as a cooling-down target after completion of the gassing-up process; and a storage tank for supply as a target for a process of supplying a liquefied gas for test operation after completion of cooling-down, the cooling-down storage tank receiving the liquefied gas along the stripping branch-off line, and the storage tank for supply receiving the liquefied gas along the liquid branch-off line.

[56] Preferably, the gassing-up storage tank includes a first gassing-up storage tank receiving the boil-off gas from the cooling-down storage tank; and a second gassing-up storage tank receiving the boil-off gas from the storage tank for supply.

[57] In accordance with yet another aspect of the present invention, there is provided a system for supplying liquefied gas fuel for ship adapted to supply a liquefied gas fuel from a liquefied gas supply vessel to a liquefied gas fuel vessel including at least two liquefied gas fuel tanks, the system for supplying liquefied gas including: a first fuel tank storing liquefied gas fuel; and a second fuel tank storing liquefied gas fuel, wherein the liquefied gas fuel is supplied from the liquefied gas supply vessel to the liquefied gas fuel vessel along a liquid branch-off line or a stripping branch-off line connected to the first fuel tank while boil-off gas discharged from the first fuel tank is supplied as a gassing-up gas to the second fuel tank along a gas line.

[58] Preferably, the gas line is provided with a compressor compressing the boil-off gas and a heater heating the boil-off gas compressed by the compressor to compress and heat the boil-off gas while the boil-off gas is transferred from the first fuel tank to the second fuel tank.

[59] Preferably, the liquefied gas fuel supply system further includes: a liquid line connecting the liquid branch-off lines to each other; and a shut-off valve disposed between a point at which the liquid branch-off line of the first fuel tank is branched off from the liquid line and a point at which a liquid branch-off line of the second fuel tank is branched off from the liquid line.

[60] Preferably, when the liquefied gas is supplied to the first fuel tank along the liquid branch-off line, the gas discharged from the second fuel tank is discharged along a liquid branch-off line connected to the second fuel tank and the shut-off valve is closed.

[61] Preferably, the liquefied gas fuel supply system further includes a first connection line connecting the liquid branch-off line of the second fuel tank to a rear end of the shut-off valve.

[62] Preferably, when the liquefied gas is supplied to the first fuel tank along the liquid branch-off line, the gas discharged from the second fuel tank is discharged to a vent mast along the liquid line and the first connection line.

【Advantageous Effects】

[63] According to embodiments of the present invention, a system and method for supplying liquefied gas to ship and system for supplying liquefied gas fuel to ship allow on-board treatment of boil-off gas generated in an LNG storage tank of an LNG carrier or an LNG fuel vessel upon supply of LNG to the LNG storage tank, such as LNG fuel tanks, without recovering the boil-off gas to an LNG supply site.

[64] In particular, upon supply of LNG to the LNG storage tank in an empty state or in test operation of the LNG carrier or the LNG fuel vessel, boil-off gas generated in a LNG cooling-down process and in an LNG supply process is treated in the LNG carrier or the LNG fuel vessel instead of being recovered to a LNG bunkering vessel.

[65] As a result, it is possible to supply LNG for test operation to the LNG carrier or the LNG fuel vessel using the LNG bunkering vessel at sea.

[66] Further, the system and method according to the embodiments allow omission of forcible vaporization of LNG for a gassing-up process.

[67] Further, the system and method according to the embodiments allow treatment of boil-off gas and supply of LNG to be simultaneously performed in a vessel to which LNG is supplied.

【Description of Drawings】

[68] FIG. 1 is a conceptual view of a liquefied gas supply system according to one embodiment of the present invention.

[69] FIG. 2 is a view illustrating a flow path upon cooling down of a fourth storage tank in the liquefied gas supply system according to the embodiment of the present invention.

[70] FIG. 3 is a view illustrating a flow path upon cooling down of a fourth storage tank in a liquefied gas supply system according to another embodiment of the present invention.

[71] FIG. 4 is a view illustrating a flow path upon supply of LNG to the fourth storage tank in the liquefied gas supply system according to the one embodiment of the present invention.

[72] FIG. 5 is a view illustrating a flow path upon supply of LNG to the fourth storage tank in the liquefied gas supply system according to another embodiment of the present invention.

[73] FIG. 6 is a conceptual view of a liquefied gas supply system of a vessel according to one embodiment of the present invention.

[74] FIG. 7 is a view illustrating a flow path upon cooling down of the first fuel tank in the liquefied gas supply system according to the one embodiment of the present invention.

[75] FIG. 8 is a view illustrating a flow path upon cooling down of the first storage tank in the liquefied gas supply system according to the one embodiment of the present invention.

[76] FIG. 9 is a view illustrating a flow path upon supply of LNG to the first fuel tank in the liquefied gas supply system according to the one embodiment of the present invention.

[77] FIG. 10 is a view illustrating a flow path upon supply of LNG to the first fuel tank in the liquefied gas supply system according to another embodiment of the present invention.

【Best Mode】

[78] The above and other advantages and objects will be become apparent from

the following detailed description of the present invention with reference to the accompanying drawings.

[79] Hereinafter, embodiments of the present invention will be described in detail with reference to the accompanying drawings. Like components will be denoted by like reference numerals throughout the accompanying drawings. It should be understood that the present invention may be embodied in different ways and is not limited to the following embodiments.

[80]

[81] In the following embodiments, liquefied gas may refer to a liquefied gas that can be produced and transported through liquefaction of a gas into a gas having a very low temperature. For example, the liquefied gas may include liquefied natural gas (LNG), liquefied ethane gas (LEG), liquefied petroleum gas (LPG), liquefied ethylene gas, liquefied propylene gas, and the like. Further, the liquefied gas may include liquefied carbon dioxide, liquefied hydrogen, liquefied ammonia, and the like. Herein, LNG will be described as the liquefied gas by way of example in the following description.

[82] In addition, although a liquefied natural gas carrier (LNG Carrier) adapted to carry liquefied natural gas as a cargo will be described as a vessel by way of example in the following embodiments, it should be understood that the present invention is applicable to any offshore structures or vessels equipped with liquefied gas storage tanks or an engine adapted to use liquefied gas as fuel, such as LNG fuel vessel including a storage tank for storing liquefied natural gas, for example, LNG FSRU (Floating Storage Regasification Unit), LNG FPSO (Floating Production Storage Offloading), LNG RV (Regasification Vessel), and the like.

[83] Further, in the following embodiments, a storage tank refers to concepts including any cargo tanks, fuel tanks, and the like, so long as the storage tank is adapted to store liquefied gas.

[84]

[85] Hereinafter, with reference to FIG. 1 to FIG. 10, a liquefied gas supply system and method for vessels and a liquefied gas fuel supply system for vessels according to embodiments of the present invention will be described.

[86] A vessel according to embodiments of the present invention includes multiple LNG storage tanks T1, T2, T3, T4, a manifold connected to an LNG supply vessel, such as an LNG bunkering vessel, or a terminal thereof to supply LNG to the multiple LNG storage tanks T1, T2, T3, T4, and fluid transfer pipes connecting the multiple LNG storage tanks T1, T2, T3, T4 to the manifold.

[87] The fluid transfer pipes include a liquefied gas line along which liquefied gas is supplied from the LNG supply vessel to one of the multiple LNG storage tanks, a gas discharge line along which boil-off gas generated in the one LNG storage tank upon supply of LNG thereto is discharged, and a gas supply line along which the boil-off gas is supplied to one or more other LNG storage tanks.

[88] In the embodiment described below, the liquefied gas line may mean a liquid line LL, liquid branch-off lines LL1, LL2, LL3, LL4, a stripping line SL, and stripping branch-off lines SL1, SL2, SL3, SL4.

[89] Further, the gas discharge line may mean a gas line GL, gas branch-off lines GL1, GL2, GL3, GL4 and first and second connection lines CL1, CL2, and may also mean a liquid line LL and liquid branch-off lines LL1, LL2, LL3, LL4 when a gas flows along the liquid line LL and the liquid branch-off lines LL1, LL2, LL3, LL4.

[90] Further, the gas supply line may mean the gas line GL and the gas branch-off lines GL1, GL2, GL3, GL4.

[91] In this embodiment, by way of example, the vessel is connected to the LNG bunkering vessel such that LNG is supplied from the LNG bunkering vessel to the LNG storage tanks T1, T2, T3, T4 through the manifold of the vessel.

[92] In this embodiment, by way of example, LNG for initial cooling down and LNG for test operation are supplied from the LNG bunkering vessel to an LNG storage tank for the purpose of test operation of the vessel. However, it should be understood that the present invention is not limited thereto and may be applied in various ways to any cases in which LNG is supplied to an LNG tank in an LNG vessel provided with at least two LNG tanks, for example, in the case where LNG is supplied to an LNG fuel tank or an LNG storage tank of the LNG vessel.

[93] Further, although not shown in the drawings, the vessel according to this

embodiment may include: a main engine that generates propulsion energy using LNG stored in the LNG storage tanks T1, T2, T3, T4 as fuel; a power generation engine that generates electric energy using LNG as fuel stored in the LNG storage tanks T1, T2, T3, T4; a fuel supply unit that supplies LNG stored in the LNG storage tanks T1, T2, T3, T4 or boil-off gas as fuel generated through natural vaporization of LNG to the main engine and the power generation engine; a reliquefaction unit that recovers a liquefied gas to the LNG storage tanks T1, T2, T3, T4 through reliquefaction of the boil-off gas; and gas treatment units 100, 200 that treat the boil-off gas or gas tripped by the engine.

[94] In addition, the LNG storage tanks T1, T2, T3, T4 may be provided in plural. According to this embodiment, as shown in FIG. 1 to FIG. 5, the vessel includes four LNG storage tanks T1, T2, T3, T4 by way of example. As such, although the vessel according to this embodiment includes four LNG storage tanks T1, T2, T3, T4, it should be understood that the present invention is not limited thereto. Further, in this embodiment, LNG storage tanks arranged from the bow to the stern will be sequentially referred to as a first storage tank T1, a second storage tank T2, a third storage tank T3, and a fourth storage tank T4, respectively.

[95] Although a manifold for liquid adapted to allow a liquid fluid to flow therein and a manifold for vapor adapted to allow a gaseous fluid to flow therein are separately provided to the vessel, FIG. 1 to FIG. 5 show only the manifold L for liquid for clear description of this embodiment of the present invention.

[96] The fluid transfer pipes include a liquid line LL and a stripping line SL disposed between the manifold L and the LNG storage tanks T1, T2, T3, T4 and adapted to transfer LNG in a liquid phase, and a gas line GL disposed therebetween and adapted to transfer natural gas in a gas phase.

[97] The liquid line LL and the stripping line SL are connected to the manifold L through a liquid crossover line LC.

[98] Upon unloading LNG from the LNG storage tanks T1, T2, T3, T4 through the manifold L and upon loading LNG to the LNG storage tanks T1, T2, T3, T4 through the manifold L, LNG may be transferred through the liquid line LL.

[99] Further, upon transfer of LNG for spraying LNG to the LNG storage tanks

T1, T2, T3, T4 through the manifold L and for stripping LNG in the LNG storage tanks T1, T2, T3, T4, LNG may flow along the stripping line SL.

[100] The vessel according to this embodiment further includes branch-off lines branched off from the liquid line LL to the LNG storage tanks T1, T2, T3, T4, respectively. More specifically, the vessel according to this embodiment further includes a first liquid line LL1 branched off from the liquid line LL to a first storage tank T1, a second liquid line LL2 branched off from the liquid line LL to a second storage tank T2, a third liquid line LL3 branched off from the liquid line LL to a third storage tank T3, and a fourth liquid line LL4 branched off from the liquid line LL to a fourth storage tank T4.

[101] The first to fourth liquid lines LL1, LL2, LL3, LL4 extend to bottom surfaces of the LNG storage tanks T1, T2, T3, T4, respectively.

[102] In addition, the vessel according to this embodiment further includes stripping branch-off lines branched off from the stripping line SL to the LNG storage tanks T1, T2, T3, T4, respectively. More specifically, the vessel according to this embodiment further includes a first stripping line SL1 branched off from the stripping line SL to the first storage tank T1, a second stripping line SL2 branched off from the stripping line SL to the second storage tank T2, a third stripping line SL3 branched off from the stripping line SL to the third storage tank T3, and a fourth stripping line SL4 branched off from the stripping line SL to the fourth storage tank T4.

[103] The first to fourth stripping lines SL1, SL2, SL3, SL4 are connected to the LNG storage tanks T1, T2, T3, T4 through liquid domes or gas domes thereof, respectively, and are connected to spray nozzles disposed on the tops of the storage tanks, respectively. That is, LNG transferred to the LNG storage tanks T1, T2, T3, T4 along the first to fourth stripping lines SL1, SL2, SL3, SL4 may be sprayed from an upper portion of each of the LNG storage tanks to a lower portion thereof.

[104] Further, the first to fourth stripping lines SL1, SL2, SL3, SL4 may extend to the lower portions of the LNG storage tanks T1, T2, T3, T4, respectively.

[105] According to this embodiment, the gas line GL connects the boil-off gas treatment units to the LNG storage tanks T1, T2, T3, T4. Although FIG. 1 to FIG. 5

show the gas line along which boil-off gas discharged from the LNG storage tanks T1, T2, T3, T4 flows, the vessel according to this embodiment may further include a vapor line along which natural gas flows in a gas phase between the manifold for the LNG storage tanks T1, T2, T3, T4 and the boil-off gas treatment units.

[106] The gas line GL includes branch-off lines connecting the gas domes of the LNG storage tanks T1, T2, T3, T4 to the boil-off gas treatment units. More specifically, the gas line GL includes a first gas line GL1 branched off from the gas line GL to the first storage tank T1, a second gas line GL2 branched off from the gas line GL to the second storage tank T2, a third gas line GL3 branched off from the gas line GL to the third storage tank T3, and a fourth gas line GL4 branched off from the gas line GL to the fourth storage tank T4.

[107] Further, although not shown in the drawings, the boil-off gas treatment units include: a boil-off gas fuel supply unit that supplies boil-off gas generated in the LNG storage tanks T1, T2, T3, T4 as fuel for an engine through compression of the boil-off gas; a reliquefaction unit that recovers the boil-off gas to the LNG storage tanks T1, T2, T3, T4 through reliquefaction of the boil-off gas, and a gas combustion unit (GCU) that treats the boil-off gas through combustion.

[108] The boil-off gas treatment units further include: a compressor 100 adapted to compress boil-off gas generated in the LNG storage tanks T1, T2, T3, T4; and a heater 200 adapted to heat the boil-off gas compressed by the compressor 100.

[109] Further, although not shown in the drawings, each of the first to fourth gas lines GL1 to GL4 may be connected to a vent mast VM through which the boil-off gas is discharged to the atmosphere. That is, the boil-off gas may be treated by venting the boil-off gas through the vent mast VM, as needed.

[110] Further, the liquefied gas supply system of the vessel according to this embodiment further includes a second connection line CL2 that connects the liquid line LL to the vent mast VM.

[111] According to this embodiment, the second connection line CL2 connects the liquid line LL to the vent mast VM. In addition, the second connection line CL2 may connect the liquid line LL to the gas dome of the first storage tank T1.

[112] The above components are fundamental components of a typical LNG

vessel and the present embodiment suggests a system that allows on-board treatment of boil-off gas generated upon supply of LNG from the LNG bunkering vessel to the vessel according to this embodiment using the fundamental components described above, without recovery of the boil-off gas to the LNG bunkering vessel.

[113] In the embodiment described below, LNG is supplied to the fourth storage tank T4. However, it should be understood that the present invention is not limited thereto and may be applied in the same way upon supply of LNG to other LNG storage tanks T1, T2, T3 for cooling down or for LNG supply.

[114] According to this embodiment, a cooling-down process and a gassing-up process for the multiple LNG storage tanks T1, T2, T3, T4 may be performed at the same time, and a supply process and the gassing-up process for the multiple LNG storage tanks T1, T2, T3, T4 may also be performed at the same time.

[115] For example, one storage tank having finished the gassing-up process may be cooled down and boil-off gas generated upon cooling down of the storage tank may be heated and supplied as a gassing-up gas to another storage tank.

[116] In addition, LNG may be supplied to the storage tank having finished the cooling down process and the boil-off gas generated upon supply of LNG to the storage tank may be heated and supplied as a gassing-up gas to another storage tank.

[117]

[118] First, referring to FIG. 2 and FIG. 3, an initial cooling-down method of the LNG storage tanks T1, T2, T3, T4 will be described. In this embodiment, a method of cooling down the fourth storage tank T4 as a cooling-down target storage tank will be described by way of example.

[119] The vessel according to this embodiment is connected to the LNG bunkering vessel through the manifold L. LNG for cooling down the fourth storage tank T4 is supplied from the LNG bunkering vessel to the fourth storage tank T4 along the liquid crossover line LC, the stripping line SL and the fourth stripping line SL4.

[120] When the LNG for cooling down is sprayed into the fourth storage tank T4, a large amount of boil-off gas is generated in the fourth storage tank T4. Here, the boil-off gas generated in the fourth storage tank T4 is supplied as a gassing-up gas to

the third storage tank T3, which is a target of the gassing-up process, along the fourth gas line GL4, the gas line GL and the third gas line GL3, thereby allowing cooling-down of the fourth storage tank T4 and gassing-up of the third storage tank T3 to be performed at the same time.

[121] Further, the boil-off gas discharged from the fourth storage tank T4 may be supplied as the gassing-up gas to the third storage tank T3 through compression by the compressor 100 and heating by the heater 200.

[122] By way of example, for a 173,400 m³ level LNG carrier, the gassing-up process is performed using about 6 to 8 MT/hr of a gas for about 6 hours for one storage tank. According to this embodiment, the boil-off gas discharged from the cooling-down storage tank, in which cooling-down is performed, is heated by the heater 200, which is a fundamental component of the vessel, and is supplied as the gassing-up gas to a gassing-up storage tank, in which the gassing-up process will be performed.

[123] That is, according to this embodiment, the gassing-up process may be performed in the gassing-up storage tank (third storage tank T3) placed near the cooling-down storage tank (fourth storage tank T4) while cooling down the cooling-down storage tank (fourth storage tank T4).

[124] As described above, an empty storage tank is filled with an inert gas due to tank drying and safety concerns. Thus, when the gassing-up gas is supplied to the third storage tank T3, the inert gas filling the third storage tank T3 is pushed by the gassing-up gas and is discharged along the third liquid line LL3.

[125] According to this embodiment, when gassing-up of the third storage tank T3 is performed while cooling down the fourth storage tank T4, the inert gas is discharged from the third storage tank T3 along the third liquid line LL3.

[126] The inert gas discharged along the third liquid line LL3 is transferred to the vent mast VM along the liquid line LL and the second connection line CL2.

[127] That is, the inert gas is transferred to the vent mast VM along the liquid line LL while LNG for cooling down is supplied to the fourth storage tank T4 along the liquid line LL.

[128] On the other hand, as shown in FIG. 2 and FIG. 3, the vessel according to

the embodiment allows on-board treatment of boil-off gas generated upon supply of LNG from the LNG bunkering vessel to the vessel using additional components and the fundamental components described above, without recovery of the boil-off gas to the LNG bunkering vessel.

[129] According to this embodiment, as additional components, the vessel may further include: a first connection line CL1 along which the liquid branch-off lines LL1, LL2, LL3, LL4 branched off from the liquid line LL and connected to the storage tanks T1, T2, T3, T4 are connected to a shut-off valve IV; and the shut-off valve IV being provided to the liquid line LL at a bow side of a connection point between the first connection line CL1 and the liquid line LL to block a flow upstream/downstream of the liquid line LL.

[130] For the vessel further including the first connection line CL1, the inert gas discharged along the third liquid line LL3 may be transferred to the vent mast VM along the first connection line CL1, the liquid line LL and the second connection line CL2.

[131] The first connection line CL1 and the second connection line CL2 may be directly connected from the third liquid line LL3 to the vent mast VM instead of being connected from the liquid line LL. Here, as a 200A standard pipe, the total length of the connecting lines CL1, CL2 may be up to 50 m with reference to 173k level vessels.

[132] By way of example, the first connection line CL1 connects the third liquid line LL3 to a point downstream of the shut-off valve IV provided to the liquid line LL.

[133] The shut-off valve IV is disposed between a point at which the liquid crossover line LC meets the liquid line LL and a point at which the liquid line LL is branched off from the point at which the liquid crossover line LC meets the liquid line LL to the LNG storage tank T4 that the liquid line LL first meets.

[134] Further, the shut-off valve IV is disposed between a point at which the first connection line CL1 is connected to the liquid line LL and a point at which the first connection line CL1 is connected to the liquid crossover line LC.

[135] That is, LNG for cooling down may be supplied to the fourth storage tank

T4 along the liquid line LL while the inert gas is transferred to the vent mast VM along the liquid line LL. Here, the shut-off valve IV is closed to block a flow upstream and downstream of the liquid line LL with reference to the shut-off valve IV.

[136] On the other hand, as shown in FIG. 3, the shut-off valve IV may be disposed at a point at which the liquid crossover line LC is connected to the liquid line LL, and may be realized by a three-way valve.

[137] Referring to FIG. 3, the shut-off valve IV is realized by the three-way valve. In this case, upon cooling down of the fourth storage tank T4 while gassing-up of the third storage tank T3 is performed as described above, the shut-off valve IV may be opened towards a side at which the third storage tank T3 is communicated with the vent mast VM and may be closed at a side at which the third storage tank T3 is communicated the liquid crossover line LC in order to prevent communication between the third storage tank T3 and the liquid crossover line LC.

[138] As such, upon cooling down of the fourth storage tank T4 while gassing-up of the third storage tank T3 is performed, the shut-off valve IV is controlled to allow communication between the crossover line LC and the stripping line SL while preventing communication between the crossover line LC and the liquid line LL.

[139]

[140] Next, referring to FIG. 4 and FIG. 5, a method of supplying LNG to the vessel according to this embodiment will be described. In this embodiment, LNG is supplied to the fourth storage tank T4 by way of example.

[141] For example, LNG may be supplied to one storage tank for supply, which has completed the gassing-up process and the cooling-down process and is ready to receive LNG, and boil-off gas generated from the storage tank for supply upon supply of LNG thereto may be heated and supplied as a gassing-up gas to another gassing-up storage tank.

[142] The amount of boil-off gas generated upon cooling down of the fourth storage tank T4 is about 120 ton/hr, which is enough to finish gassing-up of the third storage tank T3. Further, this amount of the boil-off gas is enough to partially perform the gassing-up process for another storage tank ready for gassing-up, for

example, the second storage tank T2, after gassing-up of the third storage tank T3.

[143] In the embodiment described below, by way of example, gassing-up of the second storage tank T2 is performed using the boil-off gas generated in the fourth storage tank T4 upon supply of LNG to the fourth storage tank T4 after completion of the cooling-down process.

[144] That is, as substantially described above, upon cooling-down of the fourth storage tank T4, gassing-up of the third storage tank T3, which is directly adjacent to the fourth storage tank T4, is finished. Thereafter, when LNG is supplied to the fourth storage tank T4 having finished the cooling-down process, boil-off gas is generated in the fourth storage tank T4 and may be used for gassing-up of the second storage tank T2 and/or the first storage tank T1, that is, for gassing-up of other storage tanks.

[145] In this embodiment, upon supply of LNG to the fourth storage tank T4 having finished the cooling-down process, the shut-off valve IV serves to block a flow direction of the LNG and a flow direction of the gassing-up gas in order to allow the boil-off gas discharged from the fourth storage tank T4 to be supplied as the gassing-up gas to the second storage tank T2 or the first storage tank T1.

[146] The vessel according to this embodiment is connected to the LNG bunkering vessel through the manifold L. LNG for test operation to be supplied from the LNG bunkering vessel to the fourth storage tank T4 is supplied to the fourth storage tank T4 along the liquid crossover line LC, the liquid line LL, and the fourth liquid line LL4.

[147] When LNG is supplied to the fourth storage tank T4, a large amount of boil-off gas is generated in the fourth storage tank T4. Here, the boil-off gas generated in the fourth storage tank T4 is supplied as the gassing-up gas to the second storage tank T2 through the fourth gas line GL4, the gas line GL, and the second gas line GL2, thereby enabling gassing-up of the second storage tank T2 while LNG is supplied to the fourth storage tank T4.

[148] Further, the boil-off gas discharged from the fourth storage tank T4 may be supplied as the gassing-up gas to the second storage tank T2 after being compressed by the compressor 100 and heated by the heater 200.

[149] That is, according to the embodiment, while LNG is supplied to one storage tank for supply (fourth storage tank T4), the gassing-up process may be performed for a storage tank for gassing-up (second storage tank T2) other than a storage tank (third storage tank T3), which has finished the gassing-up process upon cooling-down of the storage tank for supply (fourth storage tank T4) before supply of LNG to the storage tank for supply (fourth storage tank T4).

[150] As described above, an empty storage tank is filled with an inert gas due to tank drying and safety concerns. Thus, when the gassing-up gas is supplied to the second storage tank T2, the inert gas filling the second storage tank T2 is pushed by the gassing-up gas and is discharged along the second liquid line LL2.

[151] According to this embodiment, when gassing-up of the second storage tank T2 is performed while LNG is supplied to the fourth storage tank T4, the inert gas is discharged from the second storage tank T2 along the second liquid line LL2.

[152] The inert gas discharged along the second liquid line LL2 is transferred to the vent mast VM along the liquid line LL and the second connection line CL2.

[153] That is, the inert gas is transferred to the vent mast VM along the liquid line at the bow side with reference to the shut-off valve IV while LNG is supplied to the fourth storage tank T4 along the liquid line LL at the stern side with reference to the shut-off valve IV.

[154] Here, the shut-off valve IV is closed to block a flow in the liquid line LL at the stern side and a flow in the liquid line at the bow side with reference to the shut-off valve IV.

[155] On the other hand, as shown in FIG. 5, the shut-off valve IV may be disposed at a point at which the liquid crossover line LC is connected to the liquid line LL, and may be realized by a three-way valve.

[156] Referring to FIG. 5, the shut-off valve IV is realized by the three-way valve. In this case, as described above, upon supply of LNG to the fourth storage tank T4, that is, the storage tank for supply, while gassing-up of the second storage tank T2, that is, the gassing-up storage tank, is performed, the shut-off valve IV is controlled to allow communication between the liquid crossover line LC and a portion of the liquid line LL while preventing communication between the liquid crossover line LC

and the stripping line SL.

[157] It should be noted that, by the shut-off valve IV, the liquid crossover line LC and the liquid line LL are communicated with each other only towards the storage tank for supply, that is, the fourth storage tank T4, and are not communicated with each other towards the gassing-up storage tank, that is, the second storage tank T2.

[158] In other words, upon supply of LNG to the fourth storage tank T4 while gassing up of the second storage tank T2 is performed, although both supply of LNG to the fourth storage tank T4 and discharge of the inert gas from the second storage tank T2 are performed along the liquid line LL, the shut-off valve IV blocks a path along which LNG flows from the manifold L to the fourth storage tank T4 from a path along which the inert gas flows from the second storage tank T2 to the vent mast VM with reference to the shut-off valve IV.

[159]

[160] Next, with reference to FIG. 6 to FIG. 10, a liquefied gas fuel supply system and method of a vessel according to one embodiment of the present invention will be described.

[161] The vessel according to the embodiment of the present invention includes at least two LNG fuel tanks T1, T2, a manifold connected to an LNG supply vessel or a terminal thereof, such as an LNG bunkering vessel, in order to supply LNG to the LNG fuel tanks T1, T2, and fluid transfer pipes connecting the LNG fuel tanks T1, T2 to the manifold.

[162] The fluid transfer pipes include a liquefied gas line along which LNG is supplied from the LNG supply vessel to one of the LNG fuel tanks T1, T2, a gas discharge line along which boil-off gas generated in the one LNG fuel tank by supplying LNG to the one LNG fuel tank is discharged, and a gas supply line along which the boil-off gas is supplied to one or more other LNG storage (fuel) tanks.

[163] In the embodiment described below, the liquefied gas line may mean a liquid line LL, liquid branch-off lines LL1, LL2, a stripping line SL, and stripping branch-off lines SL1, SL2.

[164] Further, the gas discharge line may mean a gas line GL, gas branch-off

lines GL1, GL2 and a connection line CL1, and may also mean a liquid line LL and liquid branch-off lines LL1, LL2 when a gas flows along the liquid line LL and the liquid branch-off lines LL1, LL2.

[165] Further, the gas supply line may mean the gas line GL and the gas branch-off lines GL1, GL2.

[166] According to this embodiment, the vessel may be provided with multiple LNG storage tanks, which may include at least two LNG fuel tanks T1, T2. When the vessel is an LNG carrier, the vessel may further include at least one LNG cargo tank.

[167] In this embodiment, the vessel is connected to the LNG bunkering vessel such that LNG is supplied from the LNG bunkering vessel to the LNG fuel tanks T1, T2 through the manifold of the vessel. That is, a method of treating boil-off gas upon LNG bunkering will hereinafter be described by way of example.

[168] In this embodiment, by way of example, LNG for initial cooling down, LNG for test operation, or LNG as fuel is supplied from the LNG bunkering vessel to the LNG storage tank for the purpose of bunkering the vessel. However, it should be understood that the present invention is not limited thereto and may be applied to any cases in which LNG is supplied to an LNG tank in an LNG fuel vessel provided with at least two LNG tanks, for example, in the case where LNG is supplied to an LNG fuel tank in the LNG fuel vessel.

[169] Further, although not shown in the drawings, the vessel according to this embodiment may include: a main engine that generates propulsion energy using LNG as fuel stored in the LNG fuel tanks T1, T2; a power generation engine that generates electric energy using LNG as fuel stored in the LNG fuel tanks T1, T2; a fuel supply unit that supplies LNG stored in the LNG fuel tanks T1, T2, or boil-off gas generated through natural vaporization of LNG to the main engine and the power generation engine as fuel; a reliquefaction unit that recovers a liquefied gas to the LNG fuel tanks T1, T2 through reliquefaction of the boil-off gas; and gas treatment units 100, 200 that treat the boil-off gas or gas tripped by the engine.

[170] In addition, the LNG fuel tanks T1, T2 may be provided in plural. According to this embodiment, as shown in FIG. 6 to FIG. 10, the vessel includes

two LNG fuel tanks T1, T2 by way of example.

[171] As such, although the vessel according to this embodiment includes two LNG fuel tanks T1, T2, it should be understood that the present invention is not limited thereto. Further, in this embodiment, LNG fuel tanks arranged from the stern to the bow will be sequentially referred to as a first fuel tank T1 and a second fuel tank T2, respectively.

[172] Although a manifold for liquid adapted to allow a liquid fluid to flow therein and a manifold for vapor adapted to allow a gaseous fluid to flow therein are separately provided to the vessel, FIG. 6 to FIG. 10 show only the manifold L for liquid for clear description of this embodiment of the present invention.

[173] The fluid transfer pipes include a liquid line LL and a stripping line SL disposed between the manifold L and the LNG fuel tanks T1, T2 and adapted to transfer LNG in a liquid phase, and a gas line GL disposed therebetween and adapted to transfer natural gas in a gas phase.

[174] The liquid line LL and the stripping line SL are connected to the manifold L through a liquid crossover line LC.

[175] Upon unloading LNG from the LNG fuel tanks T1, T2 through the manifold L and upon loading LNG to the LNG fuel tanks T1, T2 through the manifold L, LNG may be transferred through the liquid line LL.

[176] Further, upon transfer of LNG for spraying LNG to the LNG fuel tanks T1, T2 through the manifold L and for stripping LNG in the LNG fuel tanks T1, T2, LNG may flow along the stripping line SL.

[177] The vessel according to this embodiment further includes branch-off lines branched off from the liquid line LL to the LNG fuel tanks T1, T2, respectively. More specifically, the vessel according to this embodiment further includes a first liquid line LL1 branched off from the liquid line LL to a first fuel tank T1 and a second liquid line LL2 branched off from the liquid line LL to a second fuel tank T2.

[178] The first and second liquid lines LL1, LL2 may extend to bottom surfaces of the LNG fuel tanks T1, T2 respectively.

[179] In addition, the vessel according to this embodiment further includes stripping branch-off lines branched off from the stripping line SL to the LNG fuel

tanks T1, T2, respectively. More specifically, the vessel according to this embodiment further includes a first stripping line SL1 branched off from the stripping line SL to the first fuel tank T1 and a second stripping line SL2 branched off from the stripping line SL to the second fuel tank T2.

[180] The first and second stripping lines SL1, SL2 are connected to the LNG fuel tanks T1, T2 through liquid domes or gas domes thereof, respectively, and are connected to spray nozzles disposed on the tops of the LNG fuel tanks, respectively.

[181] That is, LNG transferred to the LNG fuel tanks T1, T2 along the first and second stripping lines SL1, SL2 may be sprayed from an upper portion of each of the LNG fuel tanks to a lower portion thereof.

[182] Further, the first and second stripping lines SL1, SL2 may extend to the lower portions of the LNG fuel tanks T1, T2, respectively.

[183] According to this embodiment, the gas line GL connects the boil-off gas treatment units to the LNG fuel tanks T1, T2. Although FIG. 6 to FIG. 10 show the gas line GL along which boil-off gas discharged from the LNG fuel tanks T1, T2 flows, the vessel according to this embodiment may further include a vapor line along which natural gas flows in a gas phase between the manifold of the LNG fuel tanks T1, T2 and the boil-off gas treatment units.

[184] The gas line GL includes branch-off lines connecting the gas domes of the LNG fuel tanks T1, T2 to the boil-off gas treatment units. More specifically, the gas line GL includes a first gas line GL1 branched off from the gas line GL to the first storage tank T1 and a second gas line GL2 branched off from the gas line GL to the second storage tank T2.

[185] Further, although not shown in the drawings, the boil-off gas treatment units include: a boil-off gas fuel supply unit that supplies boil-off gas generated in the LNG fuel tanks T1, T2 as fuel for an engine through compression of the boil-off gas; a reliquefaction unit that recovers the boil-off gas to the LNG fuel tanks T1, T2 through reliquefaction of the boil-off gas, and a gas combustion unit (GCU) that treats the boil-off gas through combustion.

[186] The boil-off gas treatment units further include: a compressor 100 adapted to compress boil-off gas generated in the LNG fuel tanks T1, T2; and a heater 200

adapted to heat the boil-off gas compressed by the compressor 100.

[187] Further, although not shown in the drawings, each of the first and second gas lines GL1, GL2 may be connected to a vent mast VM through which the boil-off gas is discharged to the atmosphere. That is, the boil-off gas may be treated by venting the boil-off gas through the vent mast VM, as needed.

[188] Further, the liquefied gas fuel supply system of the vessel according to this embodiment further includes a connection line CL that connects the liquid line LL to the vent mast VM.

[189] According to this embodiment, the connection line CL connects the liquid line LL to the vent mast VM. In addition, the connection line CL may connect the liquid line LL to the gas dome of the first fuel tank T1.

[190] The above components are fundamental components of a typical LNG vessel and the present embodiment suggests a system that allows on-board treatment of boil-off gas generated upon supply of LNG from the LNG bunkering vessel to the vessel according to this embodiment using the fundamental components described above, without recovery of the boil-off gas to the LNG bunkering vessel.

[191] In the embodiment described below, LNG is supplied to the first fuel tank T1. However, it should be understood that the present invention is not limited thereto and may be applied in the same way upon supply of LNG to other LNG fuel tanks T1, T2 for cooling down or for LNG supply.

[192] According to this embodiment, a cooling-down process and a gassing-up process for at least two LNG fuel tanks T1, T2 may be performed at the same time, and a supply process and the gassing-up process for the LNG fuel tanks T1, T2 may also be performed at the same time.

[193] For example, one fuel tank (first fuel tank T1) having finished the gassing-up process may be cooled down and boil-off gas generated upon cooling down of the fuel tank may be heated and supplied as a gassing-up gas to another fuel tank (second fuel tank T2).

[194] In addition, LNG may be supplied to the fuel tank (first fuel tank T1) having finished the cooling down process and the boil-off gas generated upon supply of LNG to the fuel tank may be heated and supplied as a gassing-up gas to another

fuel tank (second fuel tank T1).

[195]

[196] Referring to FIG. 7 and FIG. 8, a method of cooling down the LNG fuel tanks T1, T2 will be described. In this embodiment, a method of cooling down the first fuel tank T1 as a fuel tank subjected to cooling down will be described by way of example.

[197] The vessel according to this embodiment is connected to the LNG bunkering vessel through the manifold L. LNG for cooling down the first fuel tank T1 is supplied from the LNG bunkering vessel to the first fuel tank T1 along the liquid crossover line LC, the stripping line SL and the first stripping line SL1.

[198] When the LNG for cooling down is sprayed into the first fuel tank T1, a large amount of boil-off gas is generated in the first fuel tank T1. Here, the boil-off gas generated in the first fuel tank T1 is supplied as a gassing-up gas to the second fuel tank T2, which is a target of the gassing-up process, along the first gas line GL1, the gas line GL and the second gas line GL2, thereby allowing cooling-down of the first fuel tank T1 and gassing-up of the second fuel tank T2 to be performed at the same time.

[199] Further, the boil-off gas discharged from the first fuel tank T1 may be supplied as the gassing-up gas to the second fuel tank T2 through compression by the compressor 100 and heating by the heater 200.

[200] By way of example, for a 173,400 m³ level LNG carrier, the gassing-up process is performed using about 6 to 8 MT/hr of a gas for about 6 hours for one fuel tank. According to this embodiment, the boil-off gas discharged from the first fuel tank T1, in which cooling-down is performed, is heated by the heater 200, which is a fundamental component of the vessel, and is supplied as the gassing-up gas to the second fuel tank T2, in which the gassing-up process will be performed.

[201] That is, according to this embodiment, the gassing-up process may be performed in a fuel tank for gassing-up (second fuel tank T2) placed near a fuel tank for cooling-down (first fuel tank T1) while cooling down the fuel tank for cooling-down (first fuel tank T1).

[202] As described above, an empty storage tank is filled with an inert gas due to

tank drying and safety concerns. Thus, when the gassing-up gas is supplied to the second fuel tank T2, the inert gas filling the second fuel tank T2 is pushed by the gassing-up gas and is discharged along the second liquid line LL2.

[203] According to this embodiment, when gassing-up of the second fuel tank T2 is performed while cooling down the first fuel tank T1, the inert gas is discharged from the second fuel tank T2 along the second liquid line LL2.

[204] The inert gas discharged along the second liquid line LL2 is transferred to the vent mast VM along the liquid line LL and the connection line CL.

[205] That is, the inert gas discharged from the second fuel tank T2 is transferred to the vent mast VM along the liquid line LL while LNG for cooling down is supplied to the first fuel tank T1 along the liquid line LL.

[206] On the other hand, as shown in FIG. 7 and FIG. 8, the vessel according to the embodiment allows on-board treatment of boil-off gas generated upon supply of LNG from the LNG bunkering vessel to the vessel using additional components and the fundamental components described above, without recovery of the boil-off gas to the LNG bunkering vessel.

[207] According to this embodiment, as an additional component, the vessel may further include a shut-off valve IV provided to the liquid line LL to block a flow upstream and downstream of the liquid line LL.

[208] The connection line CL may be directly connected from the liquid branch-off line to the vent mast VM instead of being connected from the liquid line LL. Here, as a 200A standard pipe, the total length of the connecting line CL may be up to 50 m with reference to 173k level vessels.

[209] According to this embodiment, the shut-off valve IV is disposed at a point at which the liquid crossover line LC meets the liquid line LL or between the point and a point at which one liquid branch-off line is branched off to one LNG fuel tank T1 or T2.

[210] In this embodiment and the drawings, by way of example, the shut-off valve IV is disposed between a point at which the liquid crossover line LC meets the liquid line LL and a point at which the second liquid line LL2 is branched off from the liquid line LL or a point at which the liquid crossover line LC meets the liquid

line LL.

[211] That is, LNG may be supplied to the first fuel tank T1 along the liquid line LL or the stripping line SL while the inert gas is transferred to the vent mast VM along the liquid line LL. Here, the shut-off valve IV may be closed to prevent the inert gas from flowing towards the first fuel tank T1 by blocking a flow upstream and downstream of the liquid line LL with reference to the shut-off valve IV.

[212] On the other hand, as shown in FIG. 8, the shut-off valve IV may be disposed at a point at which the liquid crossover line LC is connected to the liquid line LL, and may be realized by a three-way valve.

[213] Referring to FIG. 8, the shut-off valve IV is realized by the three-way valve. In this case, upon cooling down of the first fuel tank T1 and gassing-up of the second fuel tank T2 as described above, the shut-off valve IV may be opened towards a side at which the second fuel tank T2 is communicated with the vent mast VM and may be closed at a side at which the second fuel tank T2 is communicated with the liquid crossover line LC in order to prevent communication between the second fuel tank T2 and the liquid crossover line LC.

[214] As such, upon cooling down of the first fuel tank T1 and gassing-up of the second fuel tank T2, the shut-off valve IV is controlled to allow communication between the crossover line LC and the stripping line SL while preventing communication between the crossover line LC and the liquid line LL.

[215]

[216] Next, referring to FIG. 9 and FIG. 10, a method of supplying LNG to the vessel according to this embodiment will be described. In this embodiment, LNG is supplied to the first fuel tank T1 by way of example.

[217] For example, LNG may be supplied to one fuel tank for supply, which has completed the gassing-up process and the cooling-down process and is ready to receive LNG, and boil-off gas generated from the fuel tank for supply by supplying LNG thereto may be heated and supplied as a gassing-up gas to another fuel tank for gassing-up.

[218] The amount of boil-off gas generated upon cooling down of the first fuel tank T1 is about 120 ton/hr, which is enough to finish gassing-up of the second fuel

tank T2. Further, this amount of the boil-off gas is enough to partially perform the gassing-up process for another fuel tank for gassing-up or a cargo tank, after gassing-up of the second fuel tank T2.

[219] In the embodiment described below, by way of example, gassing-up of the second fuel tank T2 is performed using the boil-off gas generated in the first fuel tank T1 upon supply of LNG to the first fuel tank T1. That is, as substantially described above, upon cooling-down of the first fuel tank T1, gassing-up of the second fuel tank T2, which is directly adjacent to the first fuel tank T1, is finished. Thereafter, upon supply of LNG to the first fuel tank T1 having finished the cooling-down process, boil-off gas is generated in the first fuel tank T1 and may be used for gassing-up of another fuel tank or an LNG storage tank other than the fuel tank having finished gassing-up upon cooling-down of the first fuel tank T1.

[220] In this embodiment, upon supply of LNG to the first fuel tank T1 having finished the cooling-down process, the shut-off valve IV serves to block a flow direction of the LNG and a flow direction of the gassing-up gas in order to allow the boil-off gas discharged from the first fuel tank T1 to be supplied as the gassing-up gas to the second fuel tank T2 or another LNG storage tank.

[221] The vessel according to this embodiment is connected to the LNG bunkering vessel through the manifold L. LNG for test operation to be supplied from the LNG bunkering vessel to the first fuel tank T1 is supplied to the first fuel tank T1 along the liquid crossover line LC, the liquid line LL and the first liquid line LL1.

[222] When LNG is supplied to the first fuel tank T1, a large amount of boil-off gas is generated in the first fuel tank T1. Here, the boil-off gas generated in the first fuel tank T1 is supplied as the gassing-up gas to the second fuel tank T2 through the first gas line GL1, the gas line GL and the second gas line GL22, thereby enabling gassing-up of the second fuel tank T2 while LNG is supplied to the first fuel tank T1.

[223] Further, the boil-off gas discharged from the first fuel tank T1 may be supplied as the gassing-up gas to the second fuel tank T2 after being compressed by the compressor 100 and heated by the heater 200.

[224] That is, according to the embodiment of the invention, while LNG is supplied to one fuel tank for supply (first fuel tank T1), the gassing-up process may

be performed for a fuel tank for gassing-up (second fuel tank T2) other than a fuel tank, which has finished the gassing-up process upon cooling-down of the fuel tank for supply (first fuel tank T1) before supply of LNG to the fuel tank for supply (first fuel tank T1).

[225] As described above, an empty storage tank is filled with an inert gas due to tank drying and safety concerns. Thus, when the gassing-up gas is supplied to the second fuel tank T2, the inert gas filling the second fuel tank T2 is pushed by the gassing-up gas and is discharged along the second liquid line LL2.

[226] According to this embodiment, when gassing-up of the second fuel tank T2 is performed while LNG is supplied to the first fuel tank T1, the inert gas is discharged from the second fuel tank T2 along the second liquid line LL2.

[227] The inert gas discharged along the second liquid line LL2 is transferred to the vent mast VM along the liquid line LL and the connection line CL.

[228] For example, the inert gas is transferred to the vent mast VM along the liquid line at the bow side with reference to the shut-off valve IV while LNG is supplied to the first fuel tank T1 along the liquid line LL at the stern side with reference to the shut-off valve IV.

[229] Here, the shut-off valve IV is closed to block a flow in the liquid line LL at the stern side and a flow in the liquid line at the bow side with reference to the shut-off valve IV.

[230] On the other hand, as shown in FIG. 10, the shut-off valve IV may be disposed at a point at which the liquid crossover line LC is connected to the liquid line LL, and may be realized by a three-way valve.

[231]

[232] Referring to FIG. 10, the shut-off valve IV is realized by the three-way valve. In this case, as described above, upon supply of LNG to the first fuel tank T1, that is, the fuel tank for supply, while gassing-up of the second fuel tank T2, that is, the fuel tank for gassing-up, is performed, the shut-off valve IV is controlled to allow communication between the liquid crossover line LC and a portion of the liquid line LL at a side at which the first liquid line LL1 is branched off, while preventing communication between the liquid crossover line LC and the liquid line

LL at a side at which the second liquid line LL2 is branched off.

[233] It should be noted that, by the shut-off valve IV, the liquid crossover line LC and the liquid line LL are communicated with each other only towards the fuel tank for supply, that is, the first fuel tank T1, and are not communicated with each other towards the fuel tank for gassing-up, that is, the second fuel tank T2.

[234] As such, upon supply of LNG to the first fuel tank T1 while gassing up of the second fuel tank T2 is performed, although both supply of LNG to the first fuel tank T1 and discharge of the inert gas from the second fuel tank T2 are performed along the liquid line LL, the shut-off valve IV blocks a path along which LNG flows from the manifold L to the first fuel tank T1 from a path along which the inert gas flows from the second fuel tank T2 to the vent mast VM with reference to the shut-off valve IV.

[235]

[236] Although some embodiments have been described herein, it should be understood that these embodiments are provided for illustration only and are not to be construed in any way as limiting the present invention, and that various modifications, changes, alterations, and equivalent embodiments can be made by those skilled in the art without departing from the spirit and scope of the invention. Therefore, the scope of the present invention should be defined by the appended claims and equivalents thereto.

【CLAIMS】**【Claim 1】**

A system for supplying liquefied gas adapted to supply liquefied gas from a liquefied gas supply vessel to a vessel including multiple liquefied gas storage tanks, the liquefied gas supply system comprising:

a liquefied gas line along which the liquefied gas is supplied from the liquefied gas supply vessel to one of the multiple liquefied gas storage tanks;

a gas discharge line along which boil-off gas generated in the one liquefied gas storage tank upon supply of the liquefied gas thereto is discharged; and

a gas supply line along which the boil-off gas is supplied to one or more other liquefied gas storage tanks.

【Claim 2】

The liquefied gas supply system according to claim 1, further comprising:

a heater heating the boil-off gas discharged along the gas discharge line,

wherein the boil-off gas heated by the heater is supplied to one or more other liquefied gas storage tanks along the gas supply line.

【Claim 3】

The liquefied gas supply system according to claim 1, wherein the boil-off gas generated in the one liquefied gas storage tank upon supply of the liquefied gas thereto is supplied to another liquefied gas storage tank.

【Claim 4】

The liquefied gas supply system according to claim 1, wherein the boil-off gas generated in the one liquefied gas storage tank upon supply of the liquefied gas thereto is supplied to all of the other liquefied gas storage tanks.

【Claim 5】

The liquefied gas supply system according to claim 1, wherein the liquefied gas line comprises:

a liquid crossover line connecting the liquefied gas supply vessel to the liquefied gas storage tanks and adapted to transfer the liquefied gas from the liquefied gas supply vessels; and

a liquid line adapted to supply the liquefied gas to each of the liquefied gas storage tanks after division of the liquefied gas received through the liquid crossover line.

【Claim 6】

The liquefied gas supply system according to claim 5, wherein the liquid line further comprises: at least one shut-off valve blocking the liquid line to prevent the liquefied gas from being supplied to one or more other liquefied gas storage tanks upon supply of the liquefied gas along the liquid crossover line.

【Claim 7】

The liquefied gas supply system according to claim 6, wherein the shut-off valve is disposed between a point at which the liquid crossover line meets the liquid line and a point at which the liquid crossover line is branched off from the point at which the liquid crossover line meets the liquid line to a liquefied gas storage tank that the liquid line first meets.

【Claim 8】

The liquefied gas supply system according to claim 1, further comprising:

a shut-off valve provided to the liquefied gas line between the liquefied gas storage tank to which the liquefied gas is supplied along the liquefied gas line and a liquefied gas storage tank to which the boil-off gas is supplied, the shut-off valve blocking the liquefied gas line to prevent the liquefied gas and the boil-off gas flowing in the liquefied gas line from being mixed with each other,

wherein the gas supply line is used to supply the boil-off gas to the one or more other liquefied gas storage tanks by discharging the boil-off gas generated in

the one liquefied gas storage tank upon supply of the liquefied gas thereto, and
a gas discharged from the liquefied gas storage tank to which the boil-off gas is supplied is discharged along the liquefied gas line.

【Claim 9】

The liquefied gas supply system according to claim 8, further comprising:
a manifold; and
a crossover line connecting the manifold to the liquefied gas line,
wherein the shut-off valve is a three-way valve disposed at a point at which the crossover line meets the liquefied gas line.

【Claim 10】

The liquefied gas supply system according to claim 8, further comprising:
a connection line connecting the liquefied gas line to a vent mast,
wherein the gas discharged from the liquefied gas storage tank to which the boil-off gas is supplied is an inert gas, and the inert gas is transferred from the liquefied gas storage tank to the vent mast.

【Claim 11】

A method of supplying liquefied gas from a liquefied gas supply vessel to a vessel including multiple liquefied gas storage tanks, the method comprising:
a liquefied gas supply step in which the liquefied gas is supplied from the liquefied gas supply vessel to one of the multiple liquefied gas storage tanks;
a boil-off gas discharge step in which boil-off gas generated in the one liquefied gas storage tank upon supply of the liquefied gas thereto is discharged; and
a gassing-up gas supply step in which the boil-off gas discharged from the one liquefied gas storage tank is supplied to one or more other liquefied gas storage tanks.

【Claim 12】

The liquefied gas supply method according to claim 11, wherein the boil-off gas discharged in the boil-off gas discharge step is heated and supplied to one or more other liquefied gas storage tanks.

【Claim 13】

The liquefied gas supply method according to claim 11, wherein the boil-off gas generated in the one liquefied gas storage tank upon supply of the liquefied gas thereto is discharged to another liquefied gas storage tank.

【Claim 14】

The liquefied gas supply method according to claim 11, wherein the boil-off gas generated in the one liquefied gas storage tank upon supply of the liquefied gas thereto is discharged to all of the other liquefied gas storage tanks.

【Claim 15】

The liquefied gas supply method according to claim 11, wherein the liquefied gas is blocked from being supplied to one or more other liquefied gas storage tanks upon supply of the liquefied gas to one of the liquefied gas storage tanks.

【Claim 16】

The liquefied gas supply method according to claim 11, further comprising:
an inert gas discharge step in which an inert gas filling a liquefied gas storage tank to which the boil-off gas is supplied is discharged when the liquefied gas storage tank receives the boil-off gas,

wherein the inert gas is discharged along a liquefied gas supply line along which the liquefied gas is supplied to the liquefied gas storage tank.

【Claim 17】

The liquefied gas supply method according to claim 16, wherein the inert

gas discharge step comprises: a shut-off step in which a portion of the liquefied gas supply line along which the liquefied gas flows to the liquefied gas storage tank is blocked from a portion of the liquefied gas supply line along which the inert gas flows.

【Claim 18】

A system for supplying liquefied gas fuel to ship adapted to supply a liquefied gas fuel from a liquefied gas supply vessel to a liquefied gas fuel vessel including at least two liquefied gas fuel tanks, the liquefied gas fuel supply system comprising:

- a first fuel tank storing liquefied gas fuel; and
- a second fuel tank storing liquefied gas fuel,

wherein the liquefied gas fuel is supplied from the liquefied gas supply vessel to the liquefied gas fuel vessel along a liquid branch-off line or a stripping branch-off line connected to the first fuel tank while boil-off gas discharged from the first fuel tank is supplied as a gassing-up gas to the second fuel tank.

【Claim 19】

The liquefied gas fuel supply system according to claim 18, further comprising:

- a gas line along which the boil-off gas is transferred,
- the gas line being provided with a compressor compressing the boil-off gas and a heater heating the boil-off gas compressed by the compressor to compress and heat the boil-off gas while the boil-off gas is transferred from the first fuel tank to the second fuel tank.

【Claim 20】

The liquefied gas fuel supply system according to claim 18, further comprising:

- a liquid line connecting the liquid branch-off lines to each other; and
- a shut-off valve disposed between a point at which the liquid branch-off

line of the first fuel tank is branched off from the liquid line and a point at which a liquid branch-off line of the second fuel tank is branched off from the liquid line.

【Claim 21】

The liquefied gas fuel supply system according to claim 20, wherein, when the liquefied gas is supplied to the first fuel tank along the liquid branch-off line, a gas discharged from the second fuel tank is discharged along the liquid branch-off line connected to the second fuel tank and the shut-off valve is closed.

【Claim 22】

The liquefied gas fuel supply system according to claim 21, further comprising:

a connection line connecting the liquid line to a vent mast,

wherein, when the liquefied gas is supplied to the first fuel tank along the liquid branch-off line, the gas discharged from the second fuel tank is discharged to the vent mast along the liquid line and the connection line.