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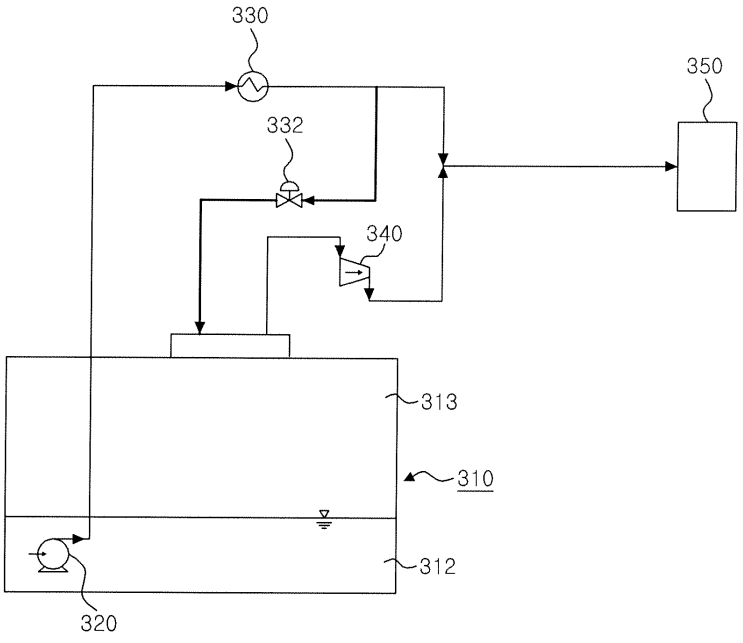
(54) Method and apparatus for supplying natural gas to gas demand sides in LNG carrier

(57) Disclosed herein is a method and apparatus for stable supply of natural gas (312) to a gas demand side (350) in an LNG carrier. With the method, natural gas comprising natural boil-off gas (313) generated in a cargo tank (310) containing LNG and forced boil-off gas generated by vaporizing LNG pumped from the cargo tank (310) is supplied to the gas demand side. The forced boil-off gas or a mixed gas of the forced boil-off gas and natural boil-off gas having a predetermined pressure or more is returned to the cargo tank or to a gas header connecting a plurality of the cargo tanks to one another to supply the natural gas at the predetermined pressure or more.

Fig. 3



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Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a method and apparatus for stable supply of natural gas to gas demand sides in an LNG carrier. More particularly, the present invention relates to a method and apparatus that enables an unstable operation of a natural boil-off gas (NBOG) compressor for fuel supply caused by a low load operation of the NBOG compressor resulting from generation of a low amount of natural boil-off gas during ballast voyage of an LNG carrier to be stabilized via operation of a forcing vaporizer under the situation of the parallel operation of the NBOG compressor and the forcing vaporizer when supplying natural gas to a gas demand side in the LNG carrier, and that can achieve stable release of the pressure at an outlet of the vaporizer with regard to variation in load of the LNG carrier.

Description of the Related Art

[0002] A liquefied natural gas (LNG) tanker is typically propelled by one or more steam turbines. Thus, the tanker is provided with a boiler to generate steam. In laden voyage, about 50% of fuel is natural boil-off gas supplied from an LNG cargo tank of the tanker. Since LNG has such a very low boiling point of about -162°C, although it is a small ratio, continuous evaporation of LNG occurs inevitably within the tanker in spite of thermal insulation of the cargo tank. Conventionally, some of the fuel required for the boiler is sufficed by using such natural boil-off gas. The remaining fuel is supplied from a stock of heavy hydrocarbon liquid fuel, which is also called "bunker oil."

[0003] To increase the total amount of steam required for propulsion of the tanker, however, it is necessary for the tanker to have the capability of generating sufficient thermal energy through the combustion of the natural gas only. For this purpose, the tanker is additionally provided with a forcing vaporizer, which is a device for supply of natural gas to a burner associated with the boiler. Furthermore, the tanker is provided with a compressor to maintain a constant pressure of the gas supplied to the burner.

[0004] As to supply of the natural boil-off gas and forced boil-off gas by the forcing vaporizer to the burner, there are two well-known methods.

[0005] In one method, the forced boil-off gas and the natural boil-off gas is mixed upstream of the compressor. For example, as set forth in Korean Utility Model Registration No. 290726 entitled "Boil-off gas supply system" and Korean Utility Model Registration No. 410367 entitled "Apparatus for supplying fuel in LNG carrier," natural boil-off gas within the LNG tank is mixed with forced boil-off gas upstream of the compressor and then supplied into the compressor.

[0006] In Korean Utility Model Registration No. 290726, gas supplied from a cargo tank 210 to a compressor 212 and a power propulsion apparatus 214 is classified into two kinds, as shown in Fig. 1. One kind of gas is natural boil-off gas generated through natural vaporization of liquefied gas within the cargo tank 210, and the other is forced boil-off gas generated through forced vaporization thereof. Both the natural boil-off gas and the forced boil-off gas are cooled to a suitable temperature range by a gas cooler 216, and supplied to the compressor 212. Here, the suitable temperature range is about -150 to -130 °C. Then, the gas is compressed in the compressor 212 and supplied at a suitable discharge pressure to the power propulsion device 214 through a discharge pipe 219.

[0007] Gas pipes 220 are positioned between the cargo tank 210 and the gas cooler 216 to form flow paths of the natural boil-off gas and the forced boil-off gas. The gas pipes 220 comprises a natural boil-off gas pipe 220a to deliver the natural boil-off gas from the cargo tank 210 to the gas cooler 216, a gas return pipe 220b to allow liquefied gas to be returned to the cargo tank 210 via the gas cooler 216 after being pumped by a gas pump 211 within the cargo tank 210, and a forced boil-off gas pipe 220c having one end diverged from an initial segment H of the gas return pipe 220b and the other end connected to the natural boil-off gas pipe 220a to deliver the forced boil-off gas from the cargo tank 210 to the gas cooler 216. The forced boil-off gas pipe 220c is provided with a vaporizer 224, which forcibly converts liquefied gas into a gaseous state.

[0008] The natural boil-off gas within the cargo tank 210 flows into the natural boil-off gas pipe 220a. Meanwhile, the liquefied gas having been pumped by the gas pump 211 flows into the gas return pipe 220b and the initial segment H of the forced boil-off gas pipe 220c.

[0009] Here, when the liquefied gas pumped by the gas pump 211 within the cargo tank 210 is forcibly vaporized through the vaporizer 224, it is mixed with the natural boil-off gas in the natural boil-off gas pipe 220a and flows together into the gas cooler 216. However, in the event that the gas pumped by the gas pump 211 is directed from the initial segment H of the gas return pipe 220b not to the vaporizer 224 but directly to the gas cooler 216, the gas is returned back to the cargo tank 210.

[0010] However, since this method is focused on temperature control of the gas upstream and downstream of the compressor and requires simultaneous compression of the forced boil-off gas and natural boil-off gas, there are shortcomings of large capacities of the compressor and motor, a complicated control method, and requirement for a mist separator (or cooler 216) to prevent liquid particles from entering the compressor.

[0011] In order to solve the problems, techniques are proposed by which the forced boil-off gas and natural boil-off gas are mixed downstream of the compressor. For example, such techniques are disclosed in Korean

Patent Laid-open Nos. 2003-0017423 and 2003-0073975. The invention disclosed in Korean Patent Laid-open No. 2003-0073975 relates to a cargo tank adapted to generate boil-off gas vaporized from LNG stored therein by heat transferred from an exterior during voyage of an LNG carrier. The cargo tank comprises: a gas dome 30 positioned on the top of the cargo tank 20 such that the boil-off gas within the cargo tank 20 is discharged through the gas dome 30; a first low duty compressor 50 connected to the gas dome 30 to raise the pressure of the boil-off gas; a gas heater 60 connected to the first low duty compressor 50 to raise the temperature of the boil-off gas; a check valve 170 disposed between the first low duty compressor 50 and the gas heater 60 to prevent a reverse flow of the boil-off gas; a second low duty compressor 180 for preparation of overhauling and inspection of the first low duty compressor 50; a constant velocity motor 40 to drive both the first and second low duty compressors 50 and 180; a boiler 90 connected to the gas heater 60 to burn the boil-off gas; a main valve 70 disposed between the gas heater 60 and an engine room 80 where the boiler 90 is positioned; a strip spray pump 100 mounted at a lower portion of the cargo tank 20 to supply LNG for supplementing gas shortage during combustion operation of the boiler 90; a flow rate control valve 120 into which a portion of LNG discharged by the strip spray pump 100 is transferred through a pressure control valve 110; a recovery line 130 connected to the pressure control valve 110 to recover LNG remaining after being transferred into the flow rate control valve 120 to the cargo tank; a temperature control valve 140 connected to the flow rate control valve 120; a vaporizer 150 connected to the flow rate control valve 120 to convert the phase of LNG from a liquid state to a gaseous state; a mixer 160 connected to the vaporizer 150 and temperature control valve 140 to mix LNG in the liquid state with LNG in the gaseous state within the mixer 160; and a boiler 90 connected to the mixer 160 to burn LNG in the gaseous state.

[0012] Details relating to pressure and temperature in the respective flow paths are shown in Figs. 1 and 2 of Korean Patent Laid-open No. 2003-0017423.

[0013] The disclosures of the publications are incorporated herein by reference.

[0014] The inventors of this invention have found that a stable operation of a natural boil-off gas (NBOG) compressor cannot be secured in the event where less gas than required for a minimum load of the NBOG compressor is induced into the NBOG compressor due to generation of a low amount of natural boil-off gas during ballast voyage of an LNG carrier, and, in the event where there is great variation in load at a gas demand side, such as a boiler, in the LNG carrier.

[0015] There is no countermeasure that can solve such problems in the prior art.

SUMMARY OF THE INVENTION

[0016] Therefore, an object of the present invention is to allow gas to be supplied at a predetermined pressure or more to a gas demand side in an LNG carrier. Another object of the present invention is to allow an NBOG compressor used for supply of fuel to the gas demand side in the LNG carrier to be operated at a relatively high load by suitably maintaining the pressure of a cargo tank, stabilizing the operation of the compressor.

[0017] In accordance with one aspect of the present invention, there is provided a method for supplying natural gas at a predetermined pressure or more to a gas demand side in an LNG carrier, the natural gas comprising natural boil-off gas generated in a cargo tank containing LNG and forced boil-off gas generated by vaporizing LNG pumped from the cargo tank, wherein in order to supply the natural gas at a predetermined pressure or more, the forced boil-off gas or a mixed gas of the forced boil-off gas and natural boil-off gas having the predetermined pressure or more is returned to the cargo tank or to a gas header connecting a plurality of the cargo tanks to one another.

[0018] The gas demand side may be any one of a boiler, a double-fuel engine, and a gas turbine.

[0019] According to one embodiment, it is necessary for the gas returned to the cargo tank to have the predetermined pressure or more, and, for this purpose, the forced boil-off gas or the mixed gas of the forced boil-off gas and natural boil-off gas is controlled to have the predetermined pressure or more in a variety of ways. For example, the forced boil-off gas or the mixed gas of the forced boil-off gas and natural boil-off gas may have the predetermined pressure or more by the forcing vaporizer. Alternatively, a separate compressor is used to control the forced boil-off gas or the mixed gas of the forced boil-off gas and natural boil-off gas to have the predetermined pressure or more while being returned to the cargo tank or the gas header, if the forced boil-off gas or the mixed gas of the forced boil-off gas and natural boil-off gas does not have the predetermined pressure or more.

[0020] Furthermore, the forced boil-off gas may be mixed with the natural boil-off gas upstream of the compressor. Preferably, the natural boil-off gas is compressed by the compressor, and the forced boil-off gas is vaporized to have the predetermined pressure or more, followed by being mixed with the natural boil-off gas compressed by the compressor.

[0021] According to the invention, since the gas having the predetermined pressure or more is returned to the cargo tank, the natural boil-off gas is maintained at the predetermined pressure or more within the cargo tank, enabling the compressor to be operated at a relatively high load, so that the compressor can be operated stably. The pressure of the gas returned to the cargo tank can be variously changed depending on the pressure range according to the specification of the compressor. In one example described below, the natural boil-off gas has an

absolute pressure of about 1.06 bars in the cargo tank and the forced boil-off gas has an absolute pressure of about 1.96 bars.

[0022] In accordance with another aspect of the invention, an apparatus for supplying natural gas to a gas demand source in an LNG carrier comprises a compressor to compress natural boil-off gas generated from a cargo tank containing LNG, a pump to pump LNG from the cargo tank and a vaporizer to vaporize the pumped LNG to generate forced boil-off gas, wherein the forced boil-off gas of the compressor is mixed with the natural boil-off gas upstream or downstream of the compressor and supplied at a predetermined pressure or more to the gas demand side, and the forced boil-off gas or mixed gas of the forced boil-off gas and natural boil-off gas having the predetermined pressure or more is returned to the cargo tank or a gas header connecting a plurality of the cargo tanks to one another.

[0023] The gas demand side may be any one of a boiler, a double-fuel engine, and a gas turbine.

[0024] The forced boil-off gas may be mixed with the natural boil-off gas before or after compression of the natural boil-off gas. Preferably, the natural boil-off gas is compressed by the compressor, and the forced boil-off gas is vaporized to have the predetermined pressure or more and mixed with the natural boil-off gas compressed by the compressor.

[0025] A separate or another compressor may be installed on a pipe, through which the forced boil-off gas or the mixed gas of the forced boil-off gas and natural boil-off gas is returned to the cargo tank or the gas header, to increase the pressure of the forced boil-off gas returned alone or in a state of being mixed with the natural boil-off gas to the cargo tank or the gas header if the pressure of the returning gas is less than or equal to a predetermined value. In the case where the forced boil-off gas is mixed with the natural boil-off gas downstream of the compressor, since the forced boil-off gas has the predetermined pressure or more when being mixed therewith downstream of the compressor, the separate compressor is not necessary.

[0026] The apparatus may further comprise a return pipe connected to downstream of the vaporizer or to downstream of a pipe joined to the return pipe through which the forced boil-off gas or the mixed gas of the forced boil-off gas and natural boil-off gas is returned to the cargo tank, and a control valve on the return pipe to control returning of the forced boil-off gas or the mixed gas by opening or closing the control valve. Since the forced boil-off gas or the mixed gas returning to the cargo tank or the header has the predetermined pressure or more, it is possible to control a returning amount of the gas only by the opening and closing of the control valve.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027] The above and other objects, features and other advantages of the present invention will be more clearly understood from the following detailed description taken in conjunction with the accompanying drawings:

Fig. 1 is a schematic view of a natural gas supply apparatus of Korean Utility Model Registration No. 290726;

Fig. 2 is a schematic view of a natural gas supply apparatus of Korean Patent Laid-open No. 2003-73975;

Fig. 3 is a schematic view illustrating an apparatus for supplying natural gas to a gas demand side in an LNG carrier according to one embodiment of the present invention; and

Fig. 4 is a schematic view illustrating an apparatus for supplying natural gas to a gas demand side in an LNG carrier according to another embodiment of the present invention.

DESCRIPTION OF THE EMBODIMENTS

[0028] Exemplary embodiments will be described in detail with reference to the accompanying drawings.

[0029] Fig. 3 is a schematic view illustrating an apparatus for supplying natural gas to a gas demand side in an LNG carrier according to one embodiment of the present invention. The construction and operation of the apparatus will be described hereinafter.

[0030] An LNG cargo tank 310 is filled with LNG 312 at a lower portion and natural boil-off gas 313 at an upper portion. The natural boil-off gas 313 generated in the cargo tank 310 is compressed by an NBOG compressor 340 after passing through an exit (dome) at the top of the cargo tank 310.

[0031] LNG 312 of the storage tank 310 is transferred to the outside of the tank by the pump 320. Since an amount of LNG is small during ballast voyage of an LNG carrier, the pump 320 is preferably a strip pump capable of pumping LNG at the bottom of the cargo tank 310.

[0032] The LNG transferred by the pump 320 is vaporized by a forcing vaporizer 330. Forced boil-off gas vaporized by the forcing vaporizer 330 is mixed with the natural boil-off gas compressed by the compressor 340 and is supplied to a gas demand side 350, for example, boilers, dual-fuel engines, gas turbines, etc.

[0033] Meanwhile, a portion of the forced boil-off gas vaporized by the forcing vaporizer 330 is returned to the cargo tank 310 through a return pipe on which a control valve 332 is disposed.

[0034] The natural boil-off gas 313 is maintained at an absolute pressure of about 1.06 bars in the cargo tank 310 and compressed to have an absolute pressure of about 1.96 bars by the compressor 340. LNG transferred from the cargo tank 310 by the pump 320 is vaporized to have an absolute pressure of about 1.96 bars by the vaporizer 330. The forced boil-off gas and compressed natural boil-off gas are supplied to the gas demand side 350 at an absolute pressure of about 1.96 bars.

[0035] Since the forced boil-off gas returning from the

forced vaporizer 330 has the absolute pressure of 1.96 bars and the natural boil-off gas in the cargo tank has the absolute pressure of about 1.06 bars, a pressure difference between the forced boil-off gas and the natural boil-off gas enables returning of the forced boil-off gas from the forcing vaporizer 330 to be easily controlled by opening or closing the control valve 332. With such a control, it is possible to supply the gas having the predetermined pressure or more required for the gas demand side. Furthermore, even when the gas demand side 350 permits only pressure variation in a predetermined range and is changed in quantity of gas demanded, it is possible to supply the gas in a predetermined pressure range by controlling a return amount of the forced boil-off gas from the forcing vaporizer 330 by the opening or closing of the control valve 332.

[0036] For example, for the double-fuel engine among various gas demand sides, the pressure must be strictly controlled to be in an allowable pressure range of ± 0.2 bars. In this case, by bypassing the forced boil-off gas supplied from the forcing vaporizer 330 to the return pipe while controlling an open or closed degree of the control valve, it is possible to supply the gas at the pressure in the predetermined range permitted at each gas demand side. Such a pressure control can be easily applied or modified by the person skilled in the art with various sensors equipped in the tanks or to various pipes of the LNG carrier.

[0037] In Fig. 3, the gas returning to the cargo tank 310 is illustrated as being the forced boil-off gas with the pressure increased to the predetermined value or more via the vaporizer 330. However, it is needless to say that mixed gas of the forced boil-off gas and the natural boil-off gas which is compressed to have the predetermined pressure or more by the compressor 340 may be returned to the cargo tank.

[0038] Furthermore, although the forced boil-off gas and the natural boil-off gas are illustrated as being mixed with each other after having a predetermined pressure or more in Fig. 3, the natural boil-off gas may be mixed with the forced boil-off gas prior to compression by the compressor 340. However, in this case, there are disadvantages in that a mist drum is required to remove liquid droplets from the forced boil-off gas and that the capacity of the compressor 340 increases. In order to return the forced boil-off gas or the mixed gas of the forced boil-off gas and natural boil-off gas having pressure lower than the predetermined degree, a separate compressor is provided to the returning pipe with a control valve 332 positioned downstream of the separate compressor.

[0039] In addition, although the forced boil-off gas from the forcing vaporizer 330 is returned to the cargo tank 310 in the embodiment shown in Fig. 3, the forced boil-off gas from the forcing vaporizer 330 may be returned to the cargo tank 310 or to a gas header 370 connecting respective cargo tanks to one another other in another embodiment shown in Fig. 4. If the forced boil-off gas is returned to the gas header 370, the forced boil-off gas can be directly supplied to a compressor 340 (for example, LD compressor) connected to the gas header 370 without being returned to the cargo tank 310 such that the allowable gas pressure for the compressor can be maintained.

[0040] The construction of the invention as described above provides various merits. For the conventional technique, in the event where less gas than required for the minimum operation load of the NBOG compressor for fuel supply is induced into the NBOG compressor due to a low amount of natural boil-off gas during ballast voyage of the LNG carrier, and, in the event where variation in load of the gas demand side is great, the stable operation of the NBOG compressor cannot be ensured. In addition, for the conventional technique, since the NBOG compressor for the fuel supply is operated below the minimum operation load thereof during the ballast voyage of the LNG carrier, the pressure of the cargo tank cannot be maintained efficiently. Furthermore, according to the conventional technique, in the event where there is a rapid variation in load at the gas demand side while the forcing vaporizer is operated in the ballast voyage or laden voyage of the LNG carrier, it is likely that pressures at the outlet of the forcing vaporizer and the inlet of the boiler will increase rapidly. Moreover, according to the conventional technique, although it is possible to operate the compressor by increasing the flow rate from the NBOG compressor using a surge control valve of the NBOG compressor, there occurs a disadvantage in that, as the gas of high temperatures downstream of the compressor circulates, the temperature of the outlet of the compressor continuously increases, making it difficult to perform the stable operation of the NBOG compressor.

[0041] In this regard, according to the invention, the return pipe and control valve associated with the return of gas to the cargo tank during the ballast voyage are provided to increase the flow rate of gas returning to the cargo tank, so that the NBOG compressor for the fuel supply can be operated at a relatively high load, enabling stable operation of the compressor and thus maintaining a suitable pressure of the cargo tank. In addition, according to the invention, since the forced boil-off gas through the forcing vaporizer is returned to the cargo tank during the ballast voyage, the pressure of the cargo tank can be properly maintained through an automatic operation via an additional pipe for load adjustment even when the NBOG compressor is operated below the minimum operation load. Furthermore, according to the invention, since the boil-off gas is returned to the cargo tank, it is possible to smoothly maintain the pressure of the cargo tank by the automatic operation thereof so as not to deteriorate the pressure of the cargo tank. With such merits of the invention, it is possible to achieve automation of a gas management system related to the boiler.

[0042] As apparent from the above description, according to the invention, gas to be supplied to the gas demand side, in particular, forced boil-off gas to be supplied from a forcing vaporizer thereto, is bypassed to a

return pipe so that natural gas can be supplied at a predetermined pressure or more required by a gas demand side, in particular, at a pressure in a predetermined range permitted by the gas demand side. Furthermore, since the gas having the predetermined pressure or more is returned to the cargo tank, the natural boil-off gas is maintained at the predetermined pressure or more within the cargo tank, enabling the compressor to be operated with a relatively high load, so that the compressor can be operated stably.

[0043] It should be understood that the embodiments and the accompanying drawings have been described for illustrative purposes, and the present invention is limited only by the following claims. Further, those skilled in the art will appreciate that various modifications, additions, and substitutions are allowed without departing from the scope and spirit of the invention according to the accompanying claims.

Claims

1. A method for supplying natural gas at a predetermined pressure or more to a gas demand side (350) in an LNG carrier, the natural gas comprising natural boil-off gas (313) generated in a cargo tank (310) containing LNG (312) and forced boil-off gas generated by vaporizing LNG pumped from the cargo tank, **Characterized in that** in order to supply the natural gas at a predetermined pressure or more, the forced boil-off gas or a mixed gas of the forced boil-off gas and natural boil-off gas (313) having the predetermined pressure or more is returned to the cargo tank (310) or to a gas header (370) connecting a plurality of the cargo tanks to one another.

2. The method according to claim 1, wherein the gas demand side (350) is any one of a boiler, a double-fuel engine, and a gas turbine.

3. The method according to claim 1 or 2, wherein the natural boil-off gas (313) is compressed by a compressor (340), and the forced boil-off gas is vaporized to have the predetermined pressure or more and mixed with the natural boil-off gas compressed by the compressor (340).

4. The method according to any one of claims 1 to 3, wherein, when the forced boil-off gas or the mixed gas of the forced boil-off gas and natural boil-off gas is returned to the cargo tank (310) or the gas header (370), the forced boil-off gas or the mixed gas is compressed by a separate compressor and returned at the predetermined pressure or more to the cargo tank or the gas header.

5. An apparatus for supplying natural gas to a gas demand side in an LNG carrier, comprising:

a compressor (340) to compress natural boil-off gas generated from a cargo tank containing LNG;
a pump (320) to pump LNG from the cargo tank; and
a vaporizer (330) to vaporize the pumped LNG to generate forced boil-off gas,

characterized in that the forced boil-off gas of the compressor is mixed with the natural boil-off gas upstream or downstream of the compressor and supplied at a predetermined pressure or more to the gas demand side, and the forced boil-off gas or mixed gas of the forced boil-off gas and natural boil-off gas having the predetermined pressure or more is returned to the cargo tank (310) or a gas header (370) connecting a plurality of the cargo tanks to one another.

6. The apparatus according to claim 5, wherein the gas demand side (350) is any one of a boiler, a double-fuel engine, and a gas turbine.

7. The apparatus according to claim 5 or 6, wherein the forced boil-off gas is mixed with the natural boil-off gas before or after compression of the natural boil-off gas (313).

8. The apparatus according to any one of claims 5 to 7, further comprising:

another compressor disposed on a pipe through which the forced boil-off gas or the mixed gas of the forced boil-off gas and natural boil-off gas is returned to the cargo tank (310) or the gas header (370).

9. The apparatus according to any one of claims 5 to 8, further comprising:

a return pipe connected to downstream of the vaporizer or to downstream of a pipe joined to the return pipe through which the forced boil-off gas or the mixed gas of the forced boil-off gas and natural boil-off gas is returned to the cargo tank; and
a control valve (332) on the return pipe to control returning of the forced boil-off gas or the mixed gas by opening or closing the control valve.

Fig. 1

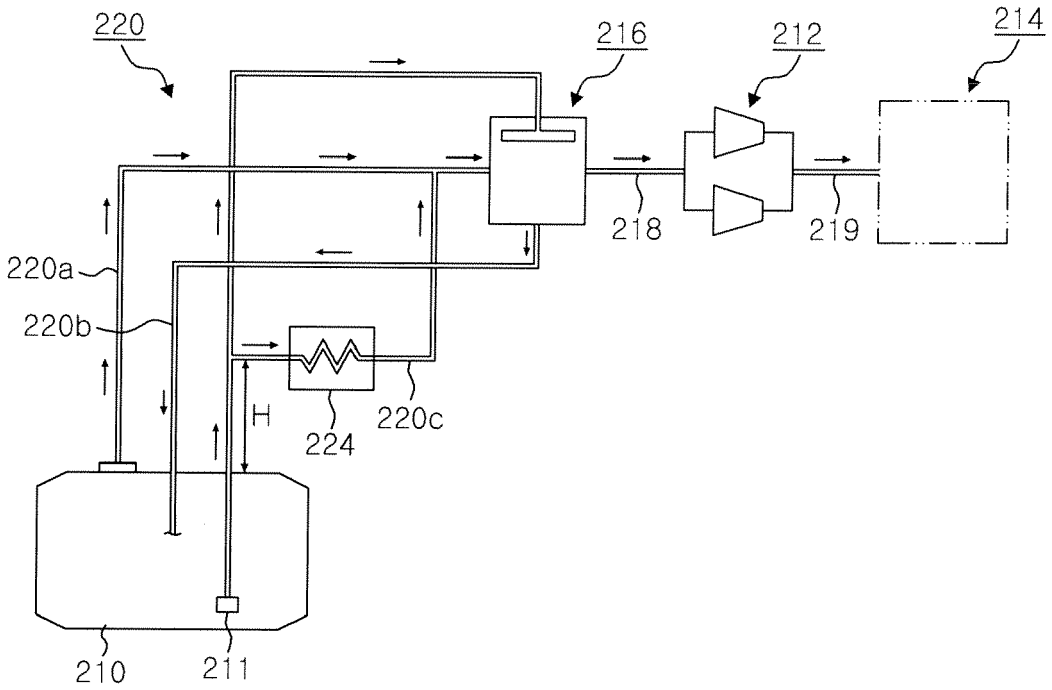


Fig. 2

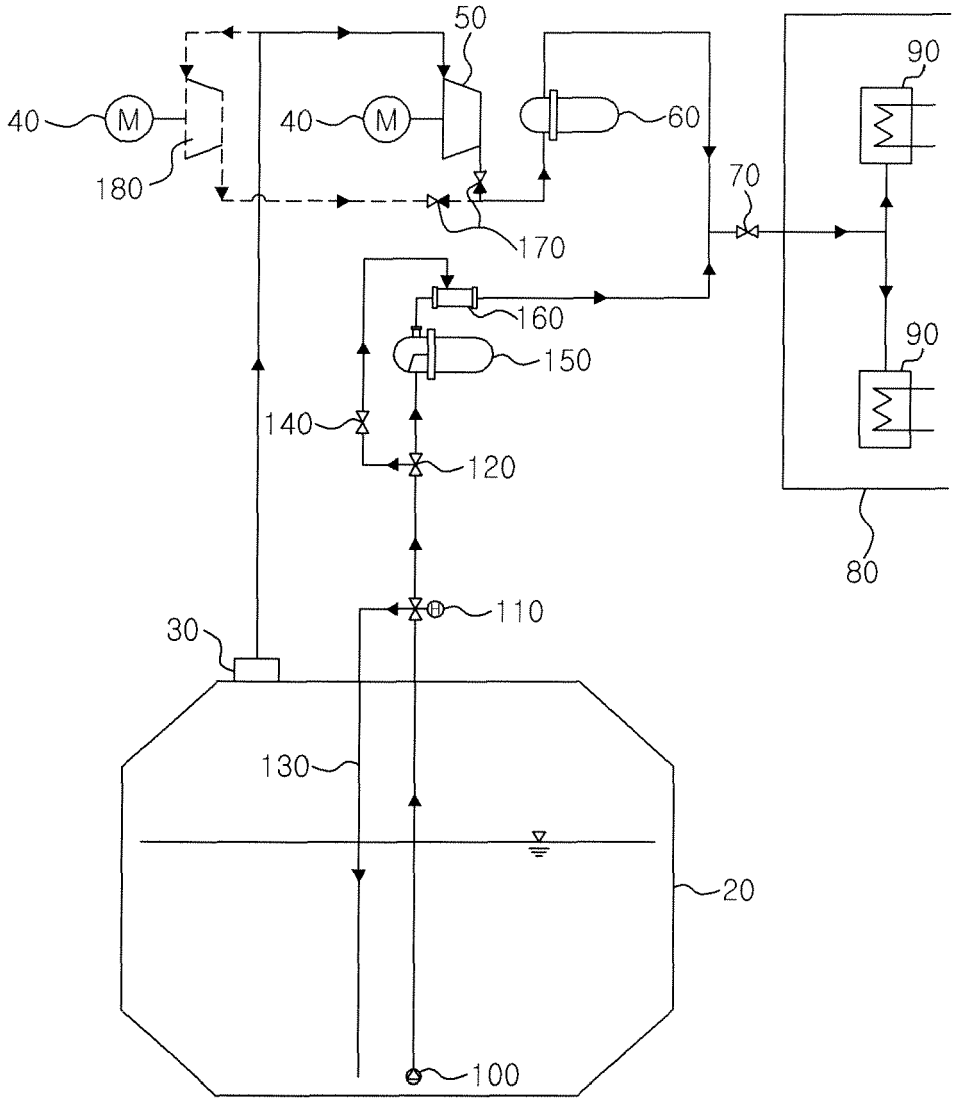


Fig. 3

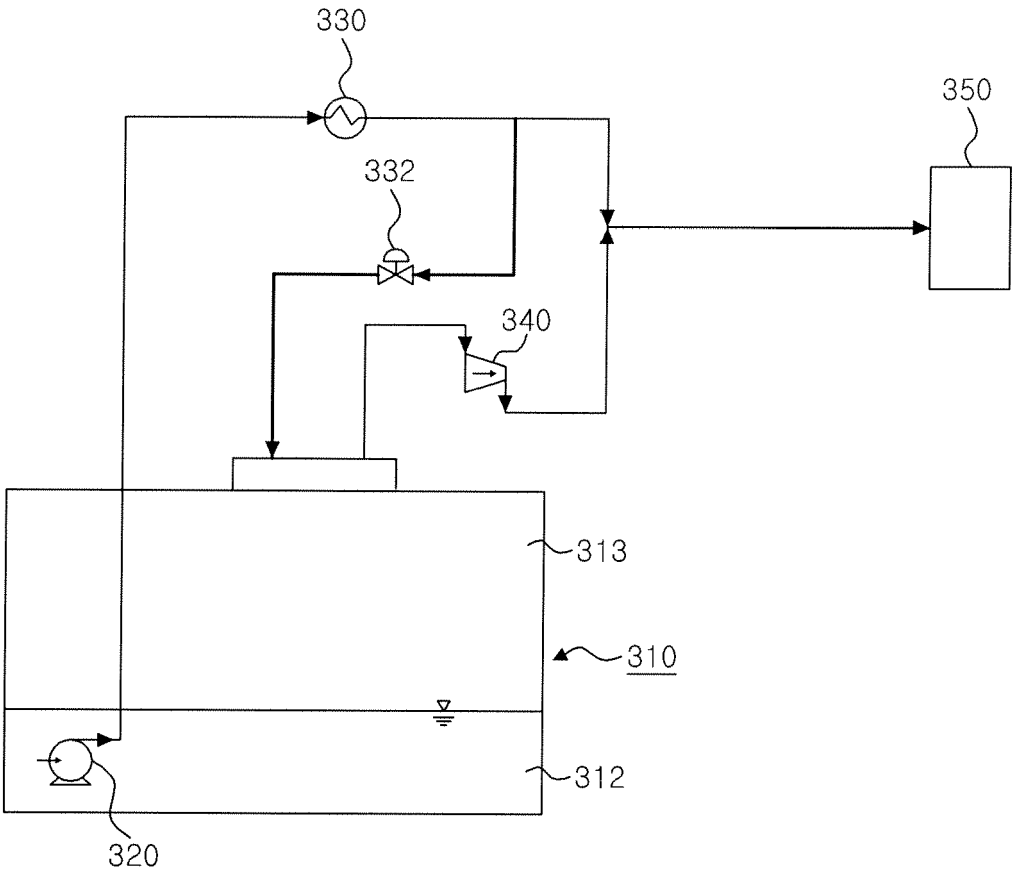
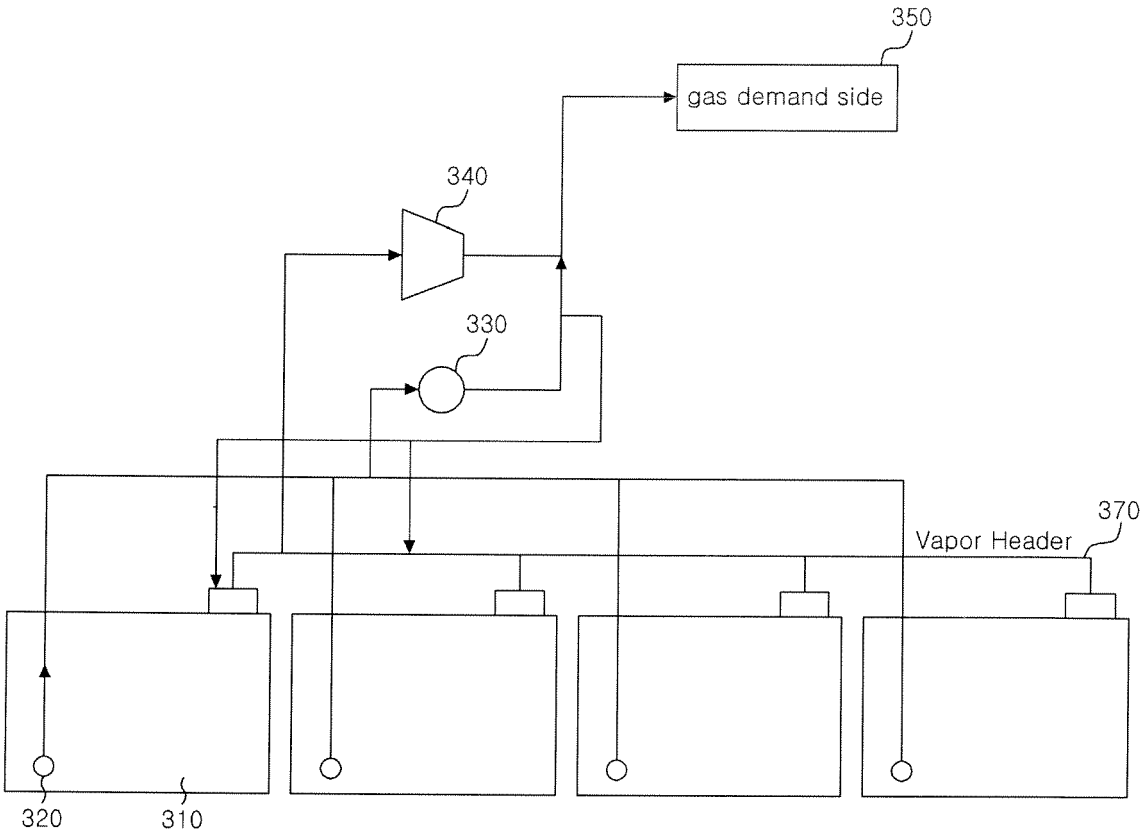


Fig. 4



REFERENCES CITED IN THE DESCRIPTION

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- KR 410367 **[0005]**
- KR 20030017423 **[0011] [0012]**
- KR 20030073975 **[0011] [0011]**
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