BOIL-OFF GAS RELIQUEFACTION DEVICE

Provided is a boil-off gas reliquefaction device that devises a disposition of equipment to be installable even in existing LNG carriers and that has a refrigeration cycle unit that reduces thermal load, is compact, and is highly efficient. The boil-off gas reliquefaction device (1) has: a liquefaction processing unit (5) having a BOG supply pipework (35), a fuel compressor (33), and a BOG transport pipework (39); and a refrigeration cycle unit (3) that further lowers the temperature of a coolant from a coolant compressor (6) by means of an expander (13) and that has a condenser (17) that cools BOG passing through the BOG transport pipework (39). The liquefaction processing unit (5) is provided with a BOG precooler (57) that performs heat exchange between BOG passing through the BOG transport pipework (39) on the upstream side of the condenser (17) and BOG passing through the BOG supply pipework (35). The refrigeration cycle unit (3) is provided with: a booster compressor (19) that is driven on the downstream side of the condenser (17) by the expander (13); and a second aftercooler (29) that cools the coolant from the booster compressor (19).
The present invention relates to a boil-off gas reliquefaction plant.

In an LNG carrier, low-temperature liquefied natural gas is stored and transported in cargo tanks at atmospheric pressure. This liquefied natural gas (LNG) is evaporated by heat input into the cargo tanks, and is accumulated in an upper portion within the cargo tanks as boil-off gas. The pressure within the cargo tanks is increased by a volume expanded due to the evaporative emission. Accordingly, it is necessary to continuously extract and process the evaporative emission.

To effectively use this boil-off gas, most LNG carriers use boil-off gas as fuel for a boiler, a gas-fired internal combustion engine, or the like, thereby supplementing a propulsive force or inboard power.

When the amount of fuel required is smaller than the amount of generated boil-off gas, surplus boil-off gas is discharged outboard, that is, the boil-off gas is wasted. Particularly, in the case of anchorage or low-speed navigation under a load state for a long period of time, the loss increases.

To suppress such a loss, a natural gas carrier (LNG carrier) including a boil-off gas reliquefaction plant that allows surplus boil-off gas to be reliquefied and returned to cargo tanks is in service (for example, see Patent Literature 1).

In the boil-off gas reliquefaction plant, the boil-off gas is cooled by the cold of a coolant circulating while changing its state along with a refrigerating cycle, and is condensed to be reliquefied.

The boil-off gas reliquefaction plant installed in the LNG carrier is required to have a compact structure so as to be housed in a narrow space in the carrier.

To further improve the liquefaction efficiency, various contrivances are made to improve the liquefaction efficiency. As disclosed in Patent Literature 1, the boil-off gas to be supplied to a refrigeration cycle part is compressed twice by two compressors to thereby improve the efficiency of heat exchange with the coolant circulating in the refrigeration cycle part, while achieving space saving in the entire apparatus.

Primary devices involving the cooling of the boil-off gas of the boil-off gas reliquefaction plant are generally disposed in a cargo machinery room at a central part of the carrier. On the other hand, a coolant compressor forming the refrigeration cycle part is a room-temperature device which is not in direct contact with the boil-off gas and requires large power. Accordingly, the coolant compressor may be disposed in an engine room in which large power-driven machines are easily installed. Furthermore, an intercooler that cools the compressed coolant is large and requires a large amount of cooling fresh water. Also in this regard, it is preferable to dispose the intercooler in the engine room in which cooling fresh water is produced.

According to the technique disclosed in Patent Literature 1, the refrigeration cycle part of the refrigeration cycle part and the intercooler attached thereto are disposed in the engine room, and only the remaining portion to be cooled is disposed in the cargo machinery room. Accordingly, when the boil-off gas reliquefaction plant is installed in the LNG carrier that uses natural gas, such as existing boil-off gas, as fuel for a boiler, for example, modification work can be drastically reduced. Even in the case of applying the boil-off gas reliquefaction plant to new ship building, the design can be easily changed.

Primary devices involving the cooling of the boil-off gas of the boil-off gas reliquefaction plant are generally disposed in a cargo machinery room at a central part of the carrier. On the other hand, a coolant compressor forming the refrigeration cycle part is a room-temperature device which is not in direct contact with the boil-off gas and requires large power. Accordingly, the coolant compressor may be disposed in an engine room in which large power-driven machines are easily installed. Furthermore, an intercooler that cools the compressed coolant is large and requires a large amount of cooling fresh water. Also in this regard, it is preferable to dispose the intercooler in the engine room in which cooling fresh water is produced.
gas reliquefaction plant that includes a small, highly-efficient refrigeration cycle part with a reduced thermal load of compressed gas precooling and devises the layout of devices to be installable even in existing LNG carriers.

Solution to Problem

[0010] To solve the above-mentioned problems, the present invention adopts the following means.

That is, a first aspect of the present invention is a boil-off gas reliquefaction plant comprising: a gas supply unit including a gas supply line that supplies a boil-off gas generated in a tank to a gas compression unit, and a compressed gas transportation line that transports the boil-off gas compressed by the gas compression unit; and a refrigeration cycle part including a condensing unit that allows a coolant cooled by a first intercooler after being compressed by the coolant compression unit to be expanded to be brought into a lower temperature state by an expander, and allows the boil-off gas transported through the compressed gas transportation line to be cooled and condensed by the coolant. The gas supply unit includes a heat exchange unit that performs heat exchange between the boil-off gas passing through the compressed gas transportation line and the boil-off gas passing through the gas supply line, the heat exchange unit being provided at an upstream side of the condensing unit.

[0011] The coolant of the refrigeration cycle part is compressed by the coolant compression unit and cooled by a first intercooler serving as an intercooler, and is then supplied to the expander. This coolant is expanded and decompressed by the expander, thereby being brought into the low-temperature state necessary for the liquefaction of the boil-off gas. The expander extracts a force obtained when the coolant is expanded, as torque, and allows a booster compressor to rotate via a directly-coupled shaft, for example. This coolant is returned to the booster compressor via the condensing unit.

On the other hand, in the gas supply unit, the boil-off gas, which is generated in the tank and supplied via the gas supply line, is compressed by the gas compression unit, and is transported through the condenser via the compressed gas transportation line.

[0012] At this time, a heat exchange unit that performs heat exchange with the boil-off gas passing through the compressed gas transportation line and the boil-off gas passing through the gas supply line is provided at an upstream side of the condensing unit. Accordingly, the boil-off gas having compressed and brought into the high-temperature state by the gas compression unit and passing through the gas supply line is cooled (pre-cooled) by the boil-off gas passing through the gas supply line and having a low temperature is introduced into the condensing unit.

The boil-off gas passing through the compressed gas transportation line is cooled by the boil-off gas obtained before being compressed by the gas compression unit. In other words, the boil-off gas is pre-cooled by the cold of the boil-off gas itself. Note that the cold of the boil-off gas passing through the compressed gas transportation line is not limited to the boil-off gas gas passing through the gas supply line, but any other gas may be added. The boil-off gas that is introduced into the condenser and cooled to a nearly condensing temperature, for example, is cooled to be condensed by the low-temperature coolant passing through the condensing unit.

[0013] In this manner, the boil-off gas having compressed and brought into the high-temperature state by the gas compression unit and passing through the compressed gas transportation line is cooled by the boil-off gas obtained before being compressed by the gas compression unit. In other words, the boil-off gas is pre-cooled by its own cold, which contributes to a reduction in load of the refrigeration cycle part by the amount corresponding to at least the amount of heat. This leads to a reduction in size of each device forming the refrigeration cycle part and downsizing of the boil-off gas reliquefaction plant.

[0014] In the first aspect, the refrigeration cycle part may include a booster compressor that compresses the coolant driven by the expander, and a second intercooler that cools the coolant to be compressed by the booster compressor and supplied to the coolant compression unit, the booster compressor and the second intercooler being provided at a downstream side of the condensing unit.

[0015] With this structure, in the refrigeration cycle part, the coolant compressed by the booster compressor is further compressed by the coolant compression unit and supplied to the expander. Accordingly, the second intercooler that cools the coolant compressed by the booster compressor is interposed between the coolant compression unit and the booster compressor. Therefore, the second intercooler can be disposed near the coolant compression unit. When the coolant compression unit is installed in an engine room, for example, the second intercooler can also be installed in the engine room. Thus, since the large second intercooler can be installed in such a relatively large engine room, the boil-off gas reliquefaction plant can be installed even in existing LNG carriers in service having a narrow cargo machinery room.

Further, a fresh water supply system is installed in the engine room. Accordingly, when the first and second intercoolers of the refrigeration cycle part are installed in the engine room, the pipes thereof can be simplified and the cooling efficiency can be improved.

[0016] A second aspect of the present invention is a boil-off gas reliquefaction plant including: a gas supply unit including a gas supply line that supplies a boil-off gas generated in a tank to a gas compression unit, and a compressed gas transportation line that transports the boil-off gas compressed by the gas compression unit; and a refrigeration cycle part including a condensing unit...
that allows a coolant cooled by a first intercooler after being compressed by a coolant compression unit to be expanded and decompressed into a lower temperature state by an expander, and allows the boil-off gas transported through the compressed gas transportation line to be cooled and condensed by the coolant. The refrigeration cycle part includes a booster compressor that is driven by the expander and compresses the coolant, and a second intercooler that cools the coolant to be compressed by the booster compressor and supplied to the coolant compression unit, the booster compressor and the second intercooler being provided at a downstream side of the condensing unit.

[0017] In the refrigeration cycle part, the coolant is compressed by the booster compressor and cooled by the second intercooler serving as an intercooler. This coolant is compressed by the coolant compression unit and cooled by the first intercooler serving as an intercooler, and is then supplied to the expander. This coolant is decompressed and expanded into a lower temperature state by the expander. The expander extracts a force obtained when the coolant is expanded, as torque, and allows the booster compressor to rotate via a directly-coupled shaft, for example.

The coolant brought into the lower temperature state is returned to the booster compressor via the condensing. On the other hand, in the gas supply unit, the boil-off gas which is generated in the tank and supplied via the gas supply line is compressed by the gas compression unit, and is transported through the conditioning unit via the compressed gas transportation line.

[0018] In this manner, in the refrigeration cycle part, the coolant compressed by the booster compressor is further compressed by the coolant compression unit and supplied to the expander. Accordingly, the second intercooler that cools the coolant compressed by the booster compressor is interposed between the coolant compression unit and the booster compressor. Therefore, since the second intercooler can be disposed near the coolant compression unit, when the coolant compression unit is installed in an engine room, for example, the second intercooler can also be installed in the engine room. Thus, since the large second intercooler can be installed in such a relatively large engine room, the boil-off gas reliquefaction plant can be installed even in existing LNG carriers in service having a narrow cargo machinery room.

Further, a fresh water supply system is installed in the engine room. Accordingly, when the first and second intercoolers of the refrigeration cycle part are installed in the engine room, the pipes thereof can be simplified and the cooling efficiency can be improved.

[0019] In each of the above-mentioned aspects, a desuperheater that cools the boil-off gas by atomizing a liquefied natural gas may be provided at an upstream side of the heat exchange unit on the gas supply line.

[0020] For example, in the case where the pipe is not cooled at the time of starting the operation of the boil-off gas reliquefaction plant, or in the case where the boil-off gas within the tank is in a relatively high-temperature state during ballast navigation, for example, the temperature of the boil-off gas passing through the gas supply line is relatively high, which may result in insufficient cold in the heat exchange unit.

In such a case, according to this aspect, the desuperheater that cools the boil-off gas by atomizing the liquefied natural gas is provided at the upstream side of the heat exchange unit on the gas supply line, thereby allowing the desuperheater to cool the boil-off gas to be supplied to the heat exchanger.

[0021] In each of the above-mentioned aspects, the gas compression unit may be structured to be divided into two stages.

[0022] With this structure, the boil-off gas is compressed twice, thereby achieving effective heat exchange with the refrigeration cycle part. This contributes to downsizing of the reliquefaction plant.

[0023] In the structure described above, a first-stage compression of the gas compression unit may be performed by a fuel gas compressor that supplies fuel to a boiler.

[0024] With this structure, for example, when the boil-off gas reliquefaction plant is installed in an LNG carrier using natural gas, such as existing boil-off gas, as fuel for a boiler, the modification work can be drastically reduced. Also in the case of applying the boil-off gas reliquefaction plant to new ship building, the design can be easily changed.

The fuel gas compressor has a relatively large capacity. However, the boil-off gas supplied to the fuel gas compressor is heated by the heat exchange unit, so that the volume of the boil-off gas is increased. Therefore, the fuel gas compressor can be used within the capacity. Accordingly, the existing fuel gas compressor can be effectively utilized for existing LNG carriers in service. Consequently, the range of the modification work can be narrowed and the modification can be made at a low price.

{Advantageous Effects of Invention}

[0025] According to the present invention, the boil-off gas having compressed and brought into a high-temperature state by the gas compression unit and passing through the compressed gas transportation line is cooled by the boil-off gas obtained before being compressed by the gas compression unit. This leads to a reduction in size of each device forming the refrigeration cycle part and downsizing of the boil-off gas reliquefaction plant. In the refrigeration cycle part, the coolant compressed by the booster compressor is further compressed by the coolant compression unit and supplied to the expander. Accordingly, the second intercooler can be disposed near the coolant compression unit. Therefore, the boil-off gas reliquefaction plant can be installed even in existing LNG carriers in service having a narrow cargo machinery room.
Hereinafter, a boil-off gas reliquefaction plant 1 of an LNG carrier according to an embodiment of the present invention will be described with reference to Fig. 1. Fig. 1 is a block diagram illustrating the overall schematic structure of the boil-off gas reliquefaction plant 1 of an LNG carrier.

The LNG carrier includes a plurality of cargo tanks (illustration thereof is omitted) that store liquefied natural gas (hereinafter referred to also as "LNG"). The cargo tanks have various forms such as a moss-type tank having a substantially spherical shape.

The boil-off gas reliquefaction plant 1 includes a refrigeration cycle part 3 and a liquefaction processing part (gas supply unit) 5.

The refrigeration cycle part 3 supplies the cold of a coolant (nitrogen is used as the coolant, for example, and hydrogen, helium, and the like are also used), which circulates through a coolant pipe 7, to the liquefaction processing part 5.

The refrigeration cycle part 3 includes, as main elements, a coolant compressor (cooler compression unit) 9, a coolant precooler 11, an expander 13, a supercooler 15, a condenser (condensing unit) 17, and a booster compressor 19.

The coolant pipe 7 forms a closed system by connecting the coolant compressor 9, the coolant precooler 11, the expander 13, the supercooler 15, the condenser 17, the coolant precooler 11, and the booster compressor 19 in the stated order.

The coolant compressor 9 is a two-stage centrifugal compressor that is driven by a steam turbine 21. The fuel gas compressors 33 are structured to selectively supply the boil-off gas (hereinafter referred to as "BOG") generated in the cargo tanks, which are not illustrated, to fuel gas compressors 33, a BOG transportation line (compressed gas transportation line) 39 that transports the BOG compressed by the fuel gas compressors 33 to a separator 37; and a reliquefied gas pipe 41 that feeds the reliquefied LNG from a separator 37 to the cargo tanks.

The BOG supply line 35 includes a mist separator 43 that cools the BOG to be transported. The mist separator 43 is structured so as to selectively supply the reliquefied LNG to a lower part of the separator 37. When the LNG is supplied from the separator 37 to the mist separator 43, the BOG is cooled by the LNG.

The liquefaction processing part 5 includes a BOG supply line (gas supply line) 35 that supplies boil-off gas (hereinafter referred to as "BOG") generated in the cargo tanks, which are not illustrated, to fuel gas compressors 33, a BOG transportation line (compressed gas transportation line) 39 that transports the BOG compressed by the fuel gas compressors 33 to a separator 37; and a reliquefied gas pipe 41 that feeds the reliquefied LNG from a separator 37 to the cargo tanks.

The BOG supply line 35 includes a mist separator (desuperheater) 43 that cools the BOG to be transported. The mist separator 43 is structured so as to selectively supply the reliquefied LNG which is stored in a storage space of the boil-off gas reliquefaction plant 1 through the expander 13, thereby eliminating the resistance thereof and making it possible to start the coolant compressor 9.

The fuel gas compressors 33 are structured to be installed so as to supply fuel to a boiler, or are installed in the case of modification. The two fuel gas compressors 33 having the same structure are disposed in parallel.
case a failure occurs. The fuel gas compressor 33 is structured so as to be driven by a motor. A free flow line 45, in which no fuel gas compressor 33 is installed, is provided in parallel with which the fuel gas compressors 33. The free flow line 45 is provided with an on-off valve 47 that is opened or closed.

A fuel pipe 49 for supplying natural gas as fuel to a boiler, which is not illustrated, is connected to an exit of each of the fuel gas compressor 33 and the free flow line 45. The fuel pipe 49 is provided with a gas heater 51 that heats the natural gas compressed by the fuel gas compressor 33.

The LNG stored in the cargo tanks separately may be gasified and supplied to each of the fuel gas compressor 33 and the free flow line 45.

The BOG transportation line 39 transports the BOG from the fuel gas compressor 33 to the separator 37 through the condenser 17. At this time, the condenser 17 allows the BOG to be cooled to be condensed by the coolant passing through the coolant pipe 7. The condenser 17 performs heat exchange only between the coolant and the BOG, thereby simplifying the structure and facilitating the design, as compared with three or more multiple heat exchange processes. This leads to an improvement in the reliability of the design.

The BOG transportation line 39 includes a BOG booster 53 that compresses the BOG, and a BOG aftercooler 55 that cools the BOG, which is compressed by the BOG booster 53 to high temperature, by using fresh water, for example.

The BOG booster 53 boosts the BOG of 160 kPaa to 450 kPaa, for example. If it is possible, any form, such as a direct cooling type screw compressor, can be used.

A BOG precooler (heat exchange unit) 57 that performs heat exchange between the BOG passing through the BOG transportation line 39 and the BOG aftercooler 55 on the BOG transportation line 39 and the condenser 17, i.e., at the upstream side of the condenser 17. The BOG precooler 57 performs heat exchange only between the coolant and the BOG, thereby simplifying the structure and facilitating the design, as compared with three or more multiple heat exchange processes. This leads to an improvement in the reliability of the design.

Note that when the BOG passing through the BOG transportation line 39 is sufficiently cooled by the BOG precooler 57, the installation of the BOG aftercooler 55 may be omitted.

The BOG supply line 35 is provided with a bypass pipe 59 that is connected and disconnected by opening and closing a valve that bypasses the BOG precooler 57.

The BOG transported through the BOG transportation line 39 is cooled to be condensed by the coolant passing through the coolant pipe 7 in the condenser 17. This condensed BOG is introduced into the separator 37 and separated into liquid and gas.

The reliquefied gas pipe 41 is connected to the cargo tank through the supercooler 15 from the lower part of the separator 37. The reliquefied gas pipe 41 is provided with a reliquefied gas flow regulating valve 61 at the downstream side of the supercooler 15.

A gas supply branch pipe 63 including a flow regulating valve, which is connected to the fuel pipe 49 from the upstream side position of the mist separator 43 on the BOG supply line 35 and the top of the separator 37, is provided.

The gas supply branch pipe 63 is structured to cool the coolant to be supplied from the coolant compressor 9 to the expander 13 through the coolant precooler 11.

The expander 13, the coolant precooler 11, the condenser 17, the supercooler 15, and the BOG precooler 57 are compactly stored in a cold box 65 having a thermal insulation structure.

The booster compressor 19 is mounted to project from the cold box 65 so as to be rotationally driven by the expander 13.

The coolant compressor 9, the coolant buffer tank 27, the steam turbine 21, the intercooler 23, the first aftercooler 25, the second aftercooler 29, and the fuel gas compressor 33 are disposed in an engine room in which the boiler is installed. The cold box 65 and the separator 37 are installed in a cargo equipment compartment.

The operation of the boil-off gas reliquefaction plant 1 according to this embodiment having the structure as described above will be described.

In the refrigeration cycle part 3, the coolant compressor 9 is driven by the steam turbine 21, and the low-temperature/low-pressure gaseous coolant introduced from the coolant pipe 7 is compressed in two stages, thereby obtaining high-temperature/high-pressure gaseous coolant. At this time, the coolant is cooled by the intercooler 23 between the first-stage compression and the second-stage compression.

This high-temperature/high-pressure gaseous coolant is cooled by the first aftercooler 25 and is introduced into the coolant precooler 11.

The coolant precooler 11, the introduced gaseous coolant is cooled by the low-temperature/low-pressure gaseous coolant returned from the condenser 17.

This coolant is introduced into the expander 13 and is expanded into low-temperature/low-pressure gaseous coolant by decompression.

This low-temperature/low-pressure gaseous coolant passes through the supercooler 15 and the condenser 17 and provides the cold to the surroundings to be cooled. After that, the coolant is heated by the coolant introduced into the expander 13 through the coolant precooler 11, and is introduced into the booster compressor 19.

The coolant is compressed and brought into high-temperature/high-pressure gaseous coolant by the booster compressor 19. This high-temperature/high-pressure gaseous coolant is cooled by the second aftercooler 29 and sent to the coolant compressor 9.
The coolant introduced into the coolant compressor 9 is further increased in temperature and pressure by the coolant compressor 9 and is then sent out. In the refrigeration cycle part 3, this cycle is continuously carried out, thereby providing the cold in the supercooler 15, the condenser 17, and the coolant precooler 11, through each of which the coolant pipe 7 passes.

[0047] The BOG generated in the cargo tanks passes the mist separator 43 and the BOG precooler 57 through the BOG supply line 35, and is supplied by the fuel gas compressor 33. The mist separator 43 is not supplied with the LNG during normal operation, and thus does not cool the BOG. For example, when the temperature of the BOG passing through the BOG supply line 35 is relatively increased in the case where the pipe is not cooled at the time of starting the operation of the boil-off gas liquefaction plant 1, or in the case where the BOG within the cargo tanks is in a relatively high-temperature state during ballast navigation, for example, the liquefied LNG from the separator 37 is supplied to the mist separator 43, and the temperature of the BOG to be supplied to the BOG precooler 57 is lowered to a necessary temperature, for example, -120°C.

[0048] The BOG introduced into the fuel gas compressor 33 is compressed by the fuel gas compressor 33 to 160 kPaa, for example. At this time, the temperature of the BOG is about 55°C, for example. After that, the BOG is boosted to 450 kPaa, for example, by the BOG booster 53. At this time, the temperature of the BOG is about 100°C, for example. This BOG is cooled to about 40°C by the BOG aftercooler 55, and is introduced into the BOG precooler 57. In the BOG precooler 57, the BOG passing through the BOG supply line 35 is cooled to about -110°C, that is, a substantially saturated liquid state, for example. On the other hand, the BOG passing through the BOG supply line 35 is boosted to about 30°C from about -120°C, for example.

[0049] The cooled BOG is cooled to be condensed by the low-temperature/low-pressure gaseous coolant that flows through the coolant pipe 7 of the refrigeration cycle part 3 during the passage through the condenser 17. The condensed BOG is sent to the separator 37. In the separator 37, the condensed BOG is separated into gas and liquid, and the liquid, which is the liquefied LNG, is stored in the lower portion and the gas is stored in the upper portion. The LNG stored in the lower portion passes through the liquefied gas pipe 41, is supercooled by the supercooler 15, and is returned to the cargo tank.

[0050] In this manner, the BOG is compressed twice by the fuel gas compressor 33 and the BOG booster 53 and is thus increased in pressure, thereby enabling effective heat exchange with the refrigeration cycle part 3. This contributes to downsizing of the refrigeration cycle part 3. Further, the BOG having been compressed and brought into a high-temperature state by the fuel gas compressor 33 and the BOG booster 53 and passing through the BOG transportation line 39 is cooled by the BOG obtained before being compressed by the fuel gas compressor 33 and passing through the BOG supply line 35 in the BOG precooler 57. In other words, the BOG is precooled by itself, thereby reducing the load of the refrigeration cycle part 3 by the amount corresponding to at least the amount of heat.

This structure enables reduction in size of the devices forming the refrigeration cycle part 3, thereby making it possible to downsizethe boil-off gas liquefaction plant 1.

[0051] In the refrigeration cycle part 3, the coolant compressed by the booster compressor 19 is further compressed by the coolant compressor 9 and supplied to the expander 13. Accordingly, the second aftercooler 29 that cools the coolant compressed by the booster compressor 19 is interposed between the coolant compressor 9 and the booster compressor 19. Therefore, the second aftercooler 29 can be disposed near the coolant compressor 9. Accordingly, when the coolant compressor 9 is installed in an engine room, for example, the second aftercooler 29 can also be installed in the engine room.

[0052] Thus, since the large second aftercooler 29 can be installed in such a relatively large engine room, the boil-off gas liquefaction plant 1 can be installed even in existing LNG carriers in service having a narrow cargo machinery room. Moreover, since the fresh water supply system is installed in the engine room, when the intercooler 23, the first aftercooler 25, and the second aftercooler 29 of the refrigeration cycle part 3 are installed in the engine room, the pipes thereof can be simplified and the cooling efficiency can be improved.

In this manner, the boil-off gas liquefaction plant 1 that is downsized and highly efficient can be achieved, and the installation space therefor can be reduced. Accordingly, in the case of installing the boil-off gas liquefaction plant 1 in the LNG carrier using natural gas, such as existing BOG, as fuel for a boiler, for example, the modification work can be drastically reduced. Also in the case of applying the boil-off gas liquefaction plant 1 to new ship building, the design can be easily changed.

[0053] In this case, the fuel gas compressor 33 has a relatively large capacity. However, the BOG supplied to the fuel gas compressor 33 is heated by the BOG precooler 57, so that the volume of the BOG is increased. Therefore, the fuel gas compressor 33 can be used within the capacity. Accordingly, the existing fuel gas compressor 33 can be effectively utilized for existing LNG carriers in service. Consequently, the range of the modification work can be narrowed and the modification can be made at a low price.

[0054] Note that the present invention is not limited to the embodiments, but can be modified as needed without departing from the gist of the present invention.
Claims

1. A boil-off gas reliquefaction plant comprising:

   a gas supply unit including a gas supply line that supplies a boil-off gas generated in a tank to a gas compression unit, and a compressed gas transportation line that transports the boil-off gas compressed by the gas compression unit; and

   a refrigeration cycle part including a condensing unit that allows the coolant cooled by a first intercooler after being compressed by the coolant compression unit to be expanded and decompressed into a lower temperature state by an expander, and allows the boil-off gas transported through the compressed gas transportation line to be cooled and condensed by the coolant, wherein the refrigeration cycle part includes a booster compressor that is driven by the expander and compresses the coolant, and a second intercooler that cools the coolant to be compressed by the booster compressor and supplied to the coolant compression unit, the booster compressor and the second intercooler being provided at a downstream side of the condensing unit.

2. The boil-off gas reliquefaction plant according to claim 1, wherein the refrigeration cycle part includes a booster compressor that compresses the coolant driven by the expander, and a second intercooler that cools the coolant to be compressed by the booster compressor and supplied to the coolant compression unit, the booster compressor and the second intercooler being provided at a downstream side of the condensing unit.

3. A boil-off gas reliquefaction plant comprising:

   a gas supply unit including a gas supply line that supplies a boil-off gas generated in a tank to a gas compression unit, and a compressed gas transportation line that transports the boil-off gas compressed by the gas compression unit; and

   a refrigeration cycle part including a condensing unit that allows the coolant cooled by a first intercooler after being compressed by a coolant compression unit to be expanded and decompressed into a lower temperature state by an expander, and allows the boil-off gas transported through the compressed gas transportation line to be cooled and condensed by the coolant, wherein the refrigeration cycle part includes a condensing unit that allows a coolant cooled by a first intercooler after being compressed by a coolant compression unit to be expanded and decompressed into a lower temperature state by an expander, and allows the boil-off gas transported through the compressed gas transportation line to be cooled and condensed by the coolant, wherein the refrigeration cycle part includes a condenser that performs heat exchange between the boil-off gas passing through the compressed gas transportation line and the boil-off gas passing through the gas supply line, the heat exchange unit being provided at an upstream side of the condensing unit.

4. The boil-off gas reliquefaction plant according to any one of claims 1 to 3, further comprising a desuperheater that cools the boil-off gas by atomizing a liquefied natural gas, the desuperheater being provided at an upstream side of the heat exchange unit on the gas supply line.

5. The boil-off gas reliquefaction plant according to any one of claims 1 to 4, wherein the gas compression unit is divided into two stages.

6. The boil-off gas reliquefaction plant according to claim 5, wherein a first-stage compression of the gas compression unit is carried out by a fuel gas compressor that supplies fuel to a boiler.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
B63B25/16(2006.01)i, C10L3/06(2006.01)i, F17C13/00(2006.01)i, F25J1/00 (2006.01)i, F25J3/06(2006.01)i

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

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
B63B25/16, C10L3/06, F17C13/00, F25J1/00, F25J3/06

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1922-1996
Kokai Jitsuyo Shinan Koho 1971-2011
Toroku Jitsuyo Shinan Koho 1994-2011

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
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<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<td>Y</td>
<td>JP 2010-25152 A (Mitsubishi Heavy Industries, Ltd.), 04 February 2010 (04.02.2010), claims 1, 3; paragraphs [0019] to [0025], [0028], [0030], [0039]; fig. 1 (Family: none)</td>
<td>1, 4-6 2-3</td>
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Further documents are listed in the continuation of Box C. See patent family annex.

Date of the actual completion of the international search
02 December, 2011 (02.12.11)

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Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

Facsimile No.

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<table>
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<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

• JP 2010025152 A [0006]