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(54) **BOIL OFF GAS RELIQUEFYING APPARATUS AND LNG SUPPLY SYSTEM PROVIDED WITH THE SAME**

(57) Provided is a boil off gas reliquefying apparatus which is applicable to new and existing liquefied natural gas tanks, and attains an extremely inexpensive investment cost.

A boil off gas reliquefying apparatus has a first line (L10), a first heat exchanger (10) for heat-exchanging BOG, a first return line (L12) that is branched from the first line (L10) in the first heat exchanger, and joins an intermediate position of a compression process line, an expander (13) that expands BOG which passes through a part of the first heat exchanger (10), a booster (14) that pressurizes BOG which is expanded by the expander (13) to pass through the first heat exchanger (10), a second heat exchanger (11) for heat-exchanging BOG which passes through the first heat exchanger (10), at least one expansion valve (16) for subjecting BOG which passes through the second heat exchanger (11) to free expansion to perform reliquefaction, and a gas-liquid separator (12) that separates BOG expanded by the expansion valve (16) into BOG and LNG.

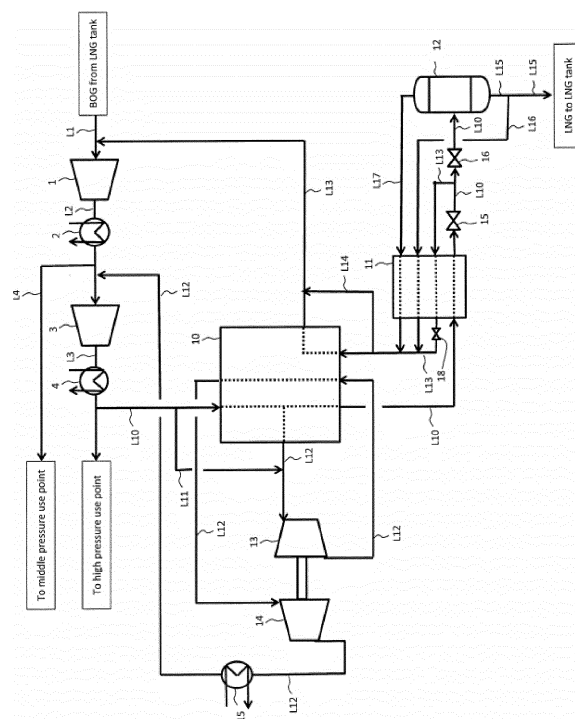


FIG. 1A

Description

[0001] The present invention relates to an apparatus that reliquefies BOG (Boil off Gas) generated from an LNG tank.

[0002] In an LNG value chain, an LNG tank is required in every situation such as a liquefied natural gas (LNG) liquefying base, a receiving base, and a bunkering base. In the LNG tank, boil off gas (BOG) is generated by heat input derived from the environment, or LNG transfer by a pump. There is concern about the adverse influence of discharge of BOG to the atmosphere on not only economic loss of hydrocarbon components such as methane but also on the air environment due to the greenhouse effect, and therefore discharged LNG is desirably used as fuel, or reliquefied to be recovered.

[0003] Non Patent Literature 1 discloses a BOG recycling process in an LNG liquefying base. In this BOG recycling process, BOG is compressed by a compressor, and BOG is utilized as fuel gas for a natural gas refining apparatus.

[0004] Patent Literature 1 discloses a method for compressing BOG in an LNG receiving base by a multistage compressor, and using the compressed BOG as fuel for power generation.

[0005] Patent Literature 2 discloses a method for reliquefying BOG compressed by a compressor, by a refrigerating cycle using nitrogen as a refrigerant.

[0006] Patent Literature 3 discloses a process of an LNG liquefying cycle including an expander/booster, a BOG compressor (compressor), a heat exchanger, and a separator. An object of this process is to supply the compressed BOG to a motor of a ship.

[0007] The processing of BOG in the conventional technologies described above is either a method for utilizing BOG as fuel or the like, or a method for reliquefying and recovering BOG in a tank.

[0008] A problem in the conventional technologies of the above Non Patent Literature 1 and Patent Literature 1 is that for example, in a case where there is no demand of fuel for power generation or the like, BOG cannot be pressure-fed by a compressor, and as a result, the BOG has to be discharged to atmosphere.

[0009] A problem in Patent Literature 2 is high cost derived from a fact that a large number of apparatuses such as a BOG compressor and a nitrogen refrigerating cycle are needed.

[0010] A problem in Patent Literature 3 is a process of supplying BOG to the motor of the ship, and a low efficiency process because optimum operation of the compressor cannot be performed, and an extra cooler is not provided. That is, a temperature at the time of manufacturing of liquid by decompression (flash) of high pressure BOG is high, and therefore a gasified amount at the time of decompression is increased, and an amount of BOG recycled in a system is increased. Therefore, a large amount of energy of compression is needed.

Citation ListPatent Literature**[0011]**

Patent Literature 1 - International Publication No. WO 2015/128903

Patent Literature 2 - Japanese Patent No. 3908881

Patent Literature 3 - Korean Patent No. 101767557

Non Patent Literature

[0012] Non Patent Literature 1 - LNG Technology, Linde Engineering, [online], [searched on January 7, 2018], Internet <URL: https://www.lindeengineering.com/internet.global.lindeengineering.global/en/images/LNG_1_1_e_13_150dpi_NB19_4577.pdf?v=8.0>

Summary of InventionTechnical Problem

[0013] An object of the present invention is to provide a boil off gas reliquefying apparatus that reliquefies boil off gas (BOG) generated from a liquefied natural gas (LNG) tank, that is applicable to new and existing liquefied natural gas (LNG) tanks, and that attains an extremely inexpensive investment cost. Additionally, another object of the present invention is to provide an LNG supply system including the boil off gas reliquefying apparatus.

Solution to Problem

[0014] The present invention is a boil off gas reliquefying apparatus for reliquefying BOG generated from an LNG tank,

and is coupled to an LNG supply system.

[0015] A first LNG supply system includes:

an LNG tank that stores LNG;

a compressor (compressor) (1) that compresses BOG having first pressure, which is sent from the LNG tank through a first pressure BOG line (L1), to increase the pressure of the compressed BOG to second pressure;

a first cooler (2) that is disposed downstream with respect to the compressor (1), and cools the BOG having the second pressure, which is sent through a second pressure BOG line (L2);

a BOG booster (3) that is disposed downstream with respect to the first cooler (2), and pressurizes the BOG sent through the second pressure BOG line (L2) such that the BOG has third pressure higher than the second pressure; a second cooler (4) that is disposed downstream with respect to the BOG booster (3), and cools the BOG having the third pressure, which is sent through a third pressure BOG line (L3); and

a second pressure BOG supply line (L4) for supplying the BOG having the second pressure, the second pressure BOG supply line being branched from the second pressure BOG line (L2).

[0016] A compression process line for performing at least one compression process on the BOG sent from the LNG tank may have the first pressure BOG line (L1), the second pressure BOG line (L2), and the third pressure BOG line (L3).

[0017] The above first boil off gas reliquefying apparatus includes:

a first line (L10) that is branched from a downstream side of a compression process line (L1, L2, L3) for performing at least one compression process on BOG sent from an LNG tank;

a first heat exchanger (10) for heat-exchanging the BOG;

a first return line (L12) that is branched from the first line (L10) in the first heat exchanger, and joins an intermediate position of the compression process line;

an expander (13) that is disposed in the first return line (L12), and expands BOG which passes through a part of the first heat exchanger (10);

a booster (14) that is disposed in the first return line (L12), pressurizes BOG expanded by the expander (13) to pass through the first heat exchanger (10), and is driven by the expander (13);

a second heat exchanger (11) for heat-exchanging BOG which passes through the first heat exchanger (10), in the first line (L10);

at least one expansion valve (16) for subjecting BOG which passes through the second heat exchanger (11) to free expansion to perform reliquefaction, in the first line (L10);

a gas-liquid separator (12) that separates BOG expanded by the expansion valve (16) into BOG and LNG;

a reliquefaction LNG line (L15) for sending LNG from the gas-liquid separator (12) to the LNG tank or a use point;

a second return line (L13) that is branched from the first line (L10) at an upstream position with respect to at least the one expansion valve (16), passes through the second heat exchanger (11), then passes through a part or a whole of the first heat exchanger (10), and joins an upstream position of the compression process line; and

a BOG line (L17) that passes through the second heat exchanger (11) from the gas-liquid separator (12) to allow the BOG to join the second return line (L13).

[0018] In the above, the first boil off gas reliquefying apparatus may further have at least one expansion valve (15) in the second return line (L13) at an upstream position with respect to the second heat exchanger (11), or upstream with respect to a branch point at which the second return line (L13) is branched from the first line (L10) and downstream with respect to the second heat exchanger (11), in the first line (L10).

[0019] A second LNG supply system is similar to the first LNG supply system.

[0020] The second boil off gas reliquefying apparatus includes:

a first line (L10) that is branched from a downstream side of a compression process line (L1, L2, L3) for performing at least one compression process on BOG sent from an LNG tank;

a first heat exchanger (10) for heat-exchanging the BOG;

a first return line (L12) that is branched from the first line (L10) in the first heat exchanger, and joins an intermediate position of the compression process line;

a first expander (33) that is disposed in the first return line (L12), and expands BOG which passes through a part of the first heat exchanger (10);

a first booster that is branched from the first return line (L12) before joining the compression process line, is disposed in a branch line (L121) joining the first line (L10) at an upstream position with respect to the first heat exchanger (10), pressurizes BOG expanded by the first expander (33) to pass through the first heat exchanger (10), and is driven by the first expander (33);

a second expander (36) that is branched from the first return line (L12) before joining the compression process line, passes through the first heat exchanger (10) once or a plurality of times, is disposed in a second return line (L122) joining an upstream position of the compression process line, and expands BOG which passes through a part of the first heat exchanger (10);

a second booster (37) that is disposed in the branch line (L121), further pressurizes the BOG, and is driven by the second expander (36);

a second heat exchanger (11) for heat-exchanging BOG which passes through the first heat exchanger (10);

at least one expansion valve (16) for subjecting BOG which passes through the second heat exchanger (11) to free expansion to perform reliquefaction;

a gas-liquid separator (12) that separates BOG expanded by the expansion valve (16) into BOG and LNG;

a reliquefaction LNG line (L15) for sending LNG from the gas-liquid separator (12) to the LNG tank or a use point; and

a BOG line (L171) that passes through a part or a whole of the first heat exchanger (10) from the gas-liquid separator (12) to allow the BOG to join the second return line (L122). The second boil off gas reliquefying apparatus having

a two-stage expander/booster can liquefy a large amount of BOG under a condition that all the expanders/boosters have the same size, compared to the first boil off gas reliquefying apparatus having a single-stage expander/booster.

[0021] An LNG supply system having a third boil off gas reliquefying apparatus includes:

an LNG tank that stores LNG;

a compressor (1) that compresses BOG sent from a second return line (L13) such that the BOG has a predetermined pressure (P2);

a BOG booster (3) that is disposed downstream with respect to the compressor (1), and pressurizes BOG sent through a BOG line (L2) such that the BOG has pressure (P3) higher than the predetermined pressure (P2);

a first line (L10) that is branched from a BOG line (L3) at a downstream position with respect to the BOG booster (3);

a first heat exchanger (10) for heat-exchanging the BOG having the pressure (P3);

a first return line (L12) that is branched from the first line (L10) in the first heat exchanger, and joins the BOG line (L2) at an upstream position with respect to the BOG booster (3);

an expander (13) that is disposed in the first return line (L12), and expands BOG which passes through a part of the first heat exchanger (10);

a booster (14) that is disposed in the first return line (L12), pressurizes BOG expanded by the expander (13) to pass through the first heat exchanger (10), and is driven by the expander (13);

a second heat exchanger (11) for heat-exchanging the BOG from the LNG tank, and the BOG which passes through the first heat exchanger (10);

at least one expansion valve (16) for subjecting BOG which passes through the second heat exchanger (11) to free expansion to perform reliquefaction;

a gas-liquid separator (separator) (12) that separates BOG expanded by the expansion valve (16) into BOG and LNG;

a reliquefaction LNG line (L15) for sending LNG from the gas-liquid separator (12) to the LNG tank or a use point;

a second return line (L13) that is branched from the first line (L10) at an upstream position with respect to at least the one expansion valve (16), passes through the second heat exchanger (11), then passes through a part or a

whole of the first heat exchanger (10), and sends BOG into the compressor (1); and

a BOG line (L17) that passes through the second heat exchanger (11) from the gas-liquid separator (12) to allow the BOG to join the second return line (L13).

[0022] In the above, the LNG supply system may further have at least one expansion valve (15) in the second return line (L13) at an upstream position with respect to the second heat exchanger (11), or upstream with respect to a branch point at which the second return line (L13) is branched from the first line (L10) and downstream with respect to the second heat exchanger (11), in the first line (L10).

[0023] In the present invention, BOG compressed in order to perform recycling, power generation, or natural gas pipeline pressure-feeding can be directly reliquefied by a liquefaction cycle. In other words, a BOG compressor used for recycling, power generation, or natural gas pipeline supply of BOG can also be used for a BOG reliquefaction cycle. That is, even in a case where there is no supply destination of BOG, reliquefaction of BOG is enabled by utilization of the compressor, exhaust of the BOG to atmosphere is eliminated. Additionally, because of a simple apparatus configuration, an apparatus can be introduced at a low cost.

[0024] The present invention is applicable to not only a new LNG facility but also remodeling utilizing a BOG compressor of an existing LNG facility, and has extremely high marketability. Compared to a conventional case where BOG is pressure-fed by a BOG compressor to be processed, the present invention can reliquefy BOG at a low cost while utilizing the BOG compressor, and can enhance flexibility in operation of an LNG facility without exhausting, to atmosphere, BOG having a strong greenhouse effect.

[0025] Compared to a conventional case where a refrigerating cycle using a nitrogen refrigerant to reliquefy BOG is applied, because of a simple apparatus configuration, a significant cost reduction is possible. For example, in a facility where BOG of 3 ton/h is processed, an apparatus cost for reliquefaction can be reduced by about 40%.

[0026] In the above, for example, an automatic switching valve, a pressure regulating valve, or a flow regulating valve may be provided in each line.

[0027] In the above, for example, a liquid feeding pump, or a pressurizer may be provided in each line.

[0028] In the above, the "pass through a whole of the heat exchanger" means that a state in which 100% of an expected heat exchange function is exerted, and the "pass through a part of the heat exchanger" means that an expected heat exchange function exceeds 0%, and is less than 100%. Unless otherwise mentioned, the "pass through the heat exchanger" has a configuration including both.

Brief Description of Drawings

[0029]

Figure 1A is a diagram illustrating a configuration example of a boil off gas reliquefying apparatus and an LNG supply system of Embodiment 1.

Figure 1B is a diagram illustrating another configuration example of Embodiment 1.

Figure 1C is a diagram illustrating another configuration example of Embodiment 1.

Figure 2 is a diagram illustrating a configuration example of a boil off gas reliquefying apparatus and an LNG supply system of Embodiment 2.

Figure 3 is a diagram illustrating a configuration example of a boil off gas reliquefying apparatus and an LNG supply system of Embodiment 3.

Description of Embodiments

[0030] Hereinafter, several embodiments of the present invention will be described. The embodiments described below each describe an example of the present invention. The present invention is not limited to the following embodiments, and includes various modified forms implemented within a scope without changing the spirit of the present invention. All configurations described below are not always essential configurations of the present invention.

(Embodiment 1)

[0031] A boil off gas reliquefying apparatus and an LNG supply system of Embodiment 1 will be described with reference to Figure 1A.

[0032] The LNG supply system has an LNG tank that stores LNG, a compressor 1 that compresses BOG having first pressure, which is sent from the LNG tank through a first pressure BOG line L1, to increase the pressure of the compressed BOG to second pressure, a first cooler 2 that is disposed downstream with respect to the compressor 1, and cools the BOG having the second pressure, which is sent through a second pressure BOG line L2, a BOG booster 3 that is disposed downstream with respect to the first cooler 2, and pressurizes the BOG sent through the second pressure BOG line L2 such that the BOG has third pressure higher than the second pressure, a second cooler 4 that is disposed downstream with respect to the BOG booster 3, and cools the BOG having the third pressure, which is sent through a third pressure BOG line L3, and a second pressure BOG supply line L4 for supplying the BOG having the second pressure, the second pressure BOG supply line being branched from the second pressure BOG line L2. The third pressure BOG line L3 is used also as a line for supplying the BOG having the third pressure.

[0033] The boil off gas reliquefying apparatus has the following configurations.

[0034] A first line L10 is branched from the third pressure BOG line L3 at a downstream position with respect to the second cooler 4, and extends as far as a first heat exchanger 10, a second heat exchanger 11, and a gas-liquid separator 12.

[0035] The first heat exchanger 10 has a capacitor function, and functions in order to heat-exchange the BOG having the third pressure.

[0036] The second heat exchanger 11 has a subcooler function, and functions in order to heat-exchange the BOG that passes through the first heat exchanger 10.

[0037] In the first line L10, a first expansion valve 15 and a second expansion valve 16 are disposed downstream with respect to the second heat exchanger 11. The first expansion valve 15 and the second expansion valve 16 function in order to subject the BOG which passes through the second heat exchanger 11 to free expansion, and reliquefy the BOG.

[0038] The gas-liquid separator 12 separates the BOG expanded by the first and second expansion valves 15 and 16 into BOG having fourth pressure lower than the third pressure, and LNG.

[0039] A reliquefaction LNG line L15 sends the LNG from the gas-liquid separator 12 to the LNG tank or a use point.

[0040] A first return line L12 is branched from the first line L10 in the first heat exchanger, and joins the second pressure BOG line L2 at an upstream position with respect to the BOG booster 3. A first branch line L11 is branched from the first line L10 at an upstream position with respect to the first heat exchanger 10, and joins the first return line L12 that comes out of the first heat exchanger 10.

[0041] In the first return line L12, an expander 13, and a booster 14 driven by the expander 13 are disposed. The expander 13 expands the BOG that passes through a part of the first heat exchanger 10. The booster 14 pressurizes the BOG that is expanded by the expander 13 to pass through the first heat exchanger 10. Then, a third cooler 35 is disposed in the first return line L12, and cools the BOG pressurized by the booster 14. The cooled BOG joins the second pressure BOG line L2 at the upstream position with respect to the BOG booster 3. A second return line L13 is branched from the first line L10 at a downstream position with respect to the first expansion valve 15 and an upstream position with respect to the second expansion valve 16, passes through the second heat exchanger 11, then passes through a part of the first heat exchanger 10, and joins the first pressure BOG line L1 at an upstream position with respect to the compressor 1.

[0042] A second branch line L14 is branched from the second return line L13 at the upstream position with respect to the first heat exchanger 10, and joins the second return line L13 that comes out of the first heat exchanger 10.

[0043] A third branch line L16 is branched from the reliquefaction LNG line L15, and passes through the second heat exchanger 11 to allow a part of the LNG to join the second return line L13.

[0044] A fourth pressure BOG line L17 passes through the second heat exchanger 11 from the gas-liquid separator 12 to allow the BOG having the fourth pressure to join the second return line L13.

[0045] In the second return line L13, a gate valve 18 may be provided at a downstream position with respect to the second heat exchanger 11.

(Other Embodiments of Embodiment 1)

[0046] An example of another embodiment of Embodiment 1 is illustrated in Figure 1B. A point of difference from Figure 1A is that a second return line L13 passes through a whole of a first heat exchanger 10.

[0047] An example of yet another embodiment of Embodiment 1 is illustrated in Figure 1C. A point of difference from Figure 1A is that only a second expansion valve 16 is disposed in a first line L10, and a first expansion valve 15 is disposed in a second return line L13.

[0048] The following are exemplified as other embodiments.

[0049] In the second return line L13, a gate valve 18 may not be disposed at the downstream position with respect to a second heat exchanger 11.

[0050] A first cooler 2 and/or a second cooler 4 is not essential, and a function stop, or a post-stage process through a bypass line may be performed in accordance with a process specification. A first branch line L11 is not essential, and may not be provided in accordance with a process specification, or may be provided with a gate valve on the line to cause to function as needed. A second branch line L14 is not essential, and may not be provided in accordance with a process specification, or may be provided with a gate valve on the line to cause to function as needed.

[0051] A third branch line L16 is not essential, and may not be provided in accordance with a process specification, or may be provided with a gate valve on the line to cause to function as needed. A configuration in which the second return line L13 passes through a part or a whole of the first heat exchanger 10 is selectable in accordance with a process specification.

[0052] The first pressure, the second pressure, the third pressure, and the fourth pressure of the BOG may be designed in accordance with a process specification.

(Embodiment 2)

[0053] A boil off gas reliquefying apparatus and an LNG supply system of Embodiment 2 will be described with reference to Figure 2. In Embodiment 2, an expander/booster has a two-stage configuration. The LNG supply system has the same configuration as the LNG supply system of Embodiment 1, and therefore description thereof will be omitted.

[0054] The boil off gas reliquefying apparatus of Embodiment 2 has the following configuration.

[0055] A first line L10 is branched from a third pressure BOG line L3 at a downstream position with respect to a second cooler 4, and extends as far as a first heat exchanger 10, a second heat exchanger 11, and a gas-liquid separator 12.

[0056] The first heat exchanger 10 has a capacitor function, and functions in order to heat-exchange BOG having third pressure.

[0057] The second heat exchanger 11 has a subcooler function, and functions in order to heat-exchange the BOG that passes through the first heat exchanger 10.

[0058] In the first line L10, an expansion valve 16 is disposed downstream with respect to the second heat exchanger

11. The expansion valve 16 functions in order to subject the BOG that passes through the second heat exchanger 11 to free expansion, and reliquefy the BOG.

[0059] A gas-liquid separator (separator) 12 separates the BOG expanded by the expansion valve 16 into BOG having fourth pressure lower than the third pressure, and LNG.

[0060] A reliquefaction LNG line L15 sends the LNG from the gas-liquid separator 12 to an LNG tank or a use point.

[0061] A first return line L12 is branched from the first line L10 in the first heat exchanger, and joins a second pressure BOG line L2 at an upstream position with respect to a BOG booster 3.

[0062] A first branch line L11 is branched from the first line L10 at an upstream position with respect to the first heat exchanger 10, and joins the first return line L12 that comes out of the first heat exchanger 10.

[0063] A first expander 33 is disposed in the first return line L12, and expands the BOG that passes through a part of the first heat exchanger 10. The first return line L12 passes through the first heat exchanger 10, and joins the second pressure BOG line L2 at a downstream position with respect to a first cooler 2. The BOG expanded by the first expander 33 is heat-exchanged by the first heat exchanger 10 again.

[0064] A fourth branch line L121 is branched from the first return line L12 before joining the second pressure BOG line L2, and joins the first line L10 at an upstream position with respect to the first heat exchanger 10. A first booster 34 is disposed in the fourth branch line L121. The first booster 34 pressurizes the BOG that is expanded by the first expander (33) to pass through the first heat exchanger 10. The first booster 34 is driven by the first expander (33). A third cooler 35 is disposed in the fourth branch line L121, and cools the BOG pressurized by the first booster 34.

[0065] A second return line L122 is branched from the first return line L12 before joining the second pressure BOG line L2, passes through the first heat exchanger 10 twice, and joins a first pressure BOG line L1 at an upstream position with respect to a compressor 1. A second expander 36 is disposed in the second return line L122. The second expander 36 expands the BOG that passes through a part of the first heat exchanger 10. The second return line L122 passes through a part (or a whole) of the first heat exchanger 10 to join the first pressure BOG line L1 at an upstream position with respect to the compressor 1. The BOG expanded by the second expander 36 is heat-exchanged by the first heat exchanger 10 again.

[0066] A second booster 37 is disposed in the fourth branch line L121. The second booster 37 further pressurizes the BOG that passes through the third cooler 35. The second booster 37 is driven by the second expander 36.

[0067] A fourth cooler 38 is disposed in the fourth branch line L121, and cools the BOG pressurized by the second booster 37.

[0068] A third branch line L16 is branched from the reliquefaction LNG line L15, passes through the second heat exchanger 11, then passes through a part or a whole of the first heat exchanger 10, and joins a part of the LNG to the second return line L122.

[0069] A fourth pressure BOG line L171 passes through a part or a whole of the first heat exchanger 10 from the gas-liquid separator 12, and allows the BOG to join the second return line L122. A fifth branch line L172 is branched from the fourth pressure BOG line L171, passes through the second heat exchanger 11, then passes through a part or a whole of the first heat exchanger 10, and joins the second return line L122.

(Other Embodiments of Embodiment 2)

[0070] A fourth pressure BOG line L171, a fifth branch line L172, and a third branch line L16 may be configured as the same line on an upstream side with respect to a first heat exchanger 10, or may be configured as separate lines.

[0071] Joining of the fourth pressure BOG line L171, the fifth branch line L172 and the third branch line L16 to a second return line L122 may be performed at an upstream position with respect to the first heat exchanger 10, may be performed in the first heat exchanger 10, or may be performed after coming out of the first heat exchanger 10.

[0072] A first cooler 2 and/or a second cooler 4 is not essential, a function stop, or a post-stage process through a bypass line may be performed in accordance with a process specification. A first branch line L11 is not essential, and may not be provided in accordance with a process specification, or may be provided with a gate valve on the line to cause to function as needed. The fifth branch line L172 is not essential, and may not be provided in accordance with a process specification, or may be provided with a gate valve on the line to cause to function as needed.

[0073] The third branch line L16 is not essential, and may not be provided in accordance with a process specification, or may be provided with a gate valve on the line to cause to function as needed.

[0074] A configuration in which the second return line L122 passes through a part or a whole of the first heat exchanger 10 is selectable in accordance with a process specification.

[0075] A configuration in which the fourth pressure BOG line L171, the fifth branch line L172, and the third branch line L16 pass through a part or a whole of the first heat exchanger 10 is selectable in accordance with a process specification.

[0076] The first pressure, the second pressure, the third pressure, and the fourth pressure of the BOG may be designed in accordance with a process specification.

(Embodiment 3)

[0077] An LNG supply system provided with a boil off gas reliquefying apparatus of Embodiment 3 will be described with reference to Figure 3.

[0078] The LNG supply system has an LNG tank that stores LNG, a compressor 1 that compresses BOG sent from a second return line L13 to increase the pressure of the compressed BOG to second pressure (P2), a first cooler 2 that is disposed downstream with respect to the compressor 1, and cools the BOG having the second pressure, which is sent through a second pressure BOG line L2, a BOG booster 3 that is disposed downstream with respect to the first cooler 2, and pressurizes the BOG sent through the second pressure BOG line L2 such that the BOG has third pressure higher than the second pressure (P2), a second cooler 4 that is disposed downstream with respect to the BOG booster 3, and cools the BOG having the third pressure (P3), which is sent through a third pressure BOG line L3, and a second pressure BOG supply line L4 that is branched from the second pressure BOG line L2, and supplies the BOG having the second pressure (P2). The third pressure BOG line L3 is used also as a line for supplying the BOG having the third pressure.

[0079] The boil off gas reliquefying apparatus has the following configurations.

[0080] A first line L10 is branched from the third pressure BOG line L3 at a downstream position with respect to the second cooler 4, and extends as far as a first heat exchanger 10, a second heat exchanger 11, and a gas-liquid separator 12.

[0081] The first heat exchanger 10 has a capacitor function, and functions in order to heat-exchange the BOG having the third pressure.

[0082] The second heat exchanger 11 has a subcooler function, and functions in order to heat-exchange the BOG that passes through the first heat exchanger 10. The second heat exchanger 11 heat-exchanges BOG supplied from the LNG tank.

[0083] In the first line L10, a first expansion valve 15 and a second expansion valve 16 are disposed downstream with respect to the second heat exchanger 11. The first expansion valve 15 and the second expansion valve 16 function in order to subject the BOG which passes through the second heat exchanger 11 to free expansion, and reliquefy the BOG.

[0084] The gas-liquid separator (separator) 12 separates the BOG expanded by the first and second expansion valves 15 and 16 into BOG having fourth pressure lower than the third pressure, and LNG.

[0085] A reliquefaction LNG line L15 sends the LNG from the gas-liquid separator 12 to the LNG tank or a use point.

[0086] A first return line L12 is branched from the first line L10 in the first heat exchanger, and joins the second pressure BOG line L2 at an upstream position with respect to the BOG booster 3. The first branch line L11 is branched from the first line L10 at an upstream position with respect to the first heat exchanger 10, and joins the first return line L12 that comes out of the first heat exchanger 10.

[0087] In the first return line L12, an expander 13, and a booster 14 driven by the expander 13 are disposed. The expander 13 expands the BOG that passes through a part of the first heat exchanger 10. The booster 14 pressurizes the BOG that is expanded by the expander 13 to pass through the first heat exchanger 10. Then, a third cooler 35 is disposed in the first return line L12, and cools the BOG pressurized by the booster 14. The cooled BOG joins the second pressure BOG line L2 at the upstream position with respect to the BOG booster 3. A second return line L13 is branched from the first line L10 at a downstream position with respect to the first expansion valve 15 and an upstream position with respect to the second expansion valve 16, and passes through the second heat exchanger 11, and then passes through a part or a whole of the first heat exchanger 10, and joins the first pressure BOG line L1 at an upstream position with respect to the compressor 1.

[0088] The BOG supplied from the LNG tank passes through the second heat exchanger 11, and joins the second return line L13.

[0089] A second branch line L14 is branched from the second return line L13 at the upstream position with respect to the first heat exchanger 10, and joins the second return line L13 that comes out of the first heat exchanger 10.

[0090] A third branch line L16 is branched from the reliquefaction LNG line L15, and passes through the second heat exchanger 11 to allow a part of the LNG to join the second return line L13. A fourth pressure BOG line L17 passes through the second heat exchanger 11 from the gas-liquid separator 12 to allow the BOG having the fourth pressure to join the second return line L13.

[0091] In the second return line L13, a gate valve 18 may be provided at a downstream position with respect to the second heat exchanger 11.

(Other Embodiments of Embodiment 3)

[0092] As another embodiment of Embodiment 3, a second return line L13 may pass through a part of a first heat exchanger 10.

[0093] Similarly to Figure 1C, only a second expansion valve 16 may be disposed in a first line L10, and a first expansion

valve 15 may be disposed in the second return line L13.

[0094] In the second return line L13, a gate valve 18 may not be provided at the downstream position with respect to a second heat exchanger 11.

[0095] A first cooler 2 and/or a second cooler 4 is not essential, and a function stop, or a post-stage process through a bypass line may be performed in accordance with a process specification. A first branch line L11 is not essential, and may not be provided in accordance with a process specification, or may be provided with a gate valve on the line to cause to function as needed. A second branch line L14 is not essential, and may not be provided in accordance with a process specification, or may be provided with a gate valve on the line to cause to function as needed.

[0096] A third branch line L16 is not essential, and may not be provided in accordance with a process specification, or may be provided with a gate valve on the line to cause to function as needed. A configuration in which the second return line L13 passes through a part or a whole of the first heat exchanger 10 is selectable in accordance with a process specification.

[0097] The first pressure, the second pressure, the third pressure, and the fourth pressure of the BOG may be designed in accordance with a process specification.

(Example)

[0098] By using the configurations of Embodiments 1 to 3 as examples, and using the configuration of Patent Literature 3 as Comparative Example, simulation was performed. A result thereof is illustrated in the following Table 1. The quantitative evaluation of Embodiments 1 to 3 to Patent Literature 3 is indicated by a ratio of SPC (Specific Power Consumption, which indicates power consumption per ton of BOG for each liquefaction source).

Table 1

	Embodiment 1	Embodiment 2	Embodiment 3	Comparative Example
Liquefaction Size [tph]	2	2.8	2	2
Estimated SPC [kWh/t]	810	1030	690	1650
SPC Ratio [%]	-51%	-38%	-58%	0%

[0099] When the result of Table 1 is considered, in Comparative Example, qualitatively, it is found that since the temperature at the time of manufacturing liquid by decompressing (flashing) high pressure BOG is high, a gasified amount at the time of decompression is increased, and an amount of BOG recycled in a system is increased, and therefore a large amount of energy for compression is needed. On the other hand, in Embodiments 1 and 2, it has been confirmed that the temperature of high pressure BOG can be further reduced by efficient arrangement of the booster/expander, and application of the subcooler function, the gasified amount at the time of decompression is reduced, and the amount of BOG to be recycled can be reduced. In Embodiment 3, it has been confirmed that the temperature of high pressure BOG is reduced by leading BOG (for example, -160°C) generated from the LNG tank to the subcooler function in order to further reduce the gasified amount at the time of decompression of high pressure BOG, and the amount of BOG to be recycled can be reduced.

Reference Signs List

[0100]

- 1 compressor
- 2 first cooler
- 3 BOG booster
- 4 second cooler
- 10 first heat exchanger
- 11 second heat exchanger
- 12 gas-liquid separator
- 15 first expansion valve
- 16 second expansion valve
- L10 first line
- L12 first return line
- L13 second return line

Claims**1.** A boil off gas reliquefying apparatus comprising:

a first line that is branched from a downstream side of a compression process line for performing at least one compression process on BOG sent from an LNG tank;
 a first heat exchanger for heat-exchanging the BOG;
 a first return line that is branched from the first line in the first heat exchanger, and joins an intermediate position of the compression process line;
 an expander that is disposed in the first return line, and expands BOG which passes through a part of the first heat exchanger;
 a booster that is disposed in the first return line, pressurizes BOG expanded by the expander to pass through the first heat exchanger, and is driven by the expander;
 a second heat exchanger for heat-exchanging BOG which passes through the first heat exchanger, in the first line;
 at least one expansion valve for subjecting BOG which passes through the second heat exchanger to free expansion to perform reliquefaction, in the first line;
 a gas-liquid separator that separates BOG expanded by the expansion valve into BOG and LNG;
 a reliquefaction LNG line for sending LNG from the gas-liquid separator to the LNG tank or a use point;
 a second return line that is branched from the first line at an upstream position with respect to at least the one expansion valve, passes through the second heat exchanger, then passes through a part or a whole of the first heat exchanger, and joins an upstream position of the compression process line; and
 a BOG line that passes through the second heat exchanger from the gas-liquid separator to allow the BOG to join the second return line.

2. The boil off gas reliquefying apparatus according to claim 1, further comprising at least one expansion valve in the second return line at an upstream position with respect to the second heat exchanger, or upstream with respect to a branch point at which the second return line is branched from the first line and downstream with respect to the second heat exchanger, in the first line.

3. A boil off gas reliquefying apparatus comprising:

a first line that is branched from a downstream side of a compression process line for performing at least one compression process on BOG sent from an LNG tank;
 a first heat exchanger for heat-exchanging the BOG;
 a first return line that is branched from the first line in the first heat exchanger, and joins an intermediate position of the compression process line;
 a first expander that is disposed in the first return line, and expands BOG which passes through a part of the first heat exchanger;
 a first booster that is branched from the first return line before joining the compression process line, is disposed in a branch line joining the first line at an upstream position with respect to the first heat exchanger, pressurizes BOG expanded by the first expander to pass through the first heat exchanger, and is driven by the first expander;
 a second expander that is branched from the first return line before joining the compression process line, passes through the first heat exchanger once or a plurality of times, is disposed in a second return line joining an upstream position of the compression process line, and expands the BOG which passes through a part of the first heat exchanger;
 a second booster that is disposed in the branch line, further pressurizes the BOG, and is driven by the second expander;
 a second heat exchanger for heat-exchanging BOG which passes through the first heat exchanger;
 at least one expansion valve for subjecting BOG which passes through the second heat exchanger to free expansion to perform reliquefaction;
 a gas-liquid separator that separates BOG expanded by the expansion valve into BOG and LNG;
 a reliquefaction LNG line for sending LNG from the gas-liquid separator to the LNG tank or a use point; and
 a BOG line that passes through a part or a whole of the first heat exchanger from the gas-liquid separator to allow the BOG to join the second return line.

4. An LNG supply system comprising:

an LNG terminal tank; and

the boil off gas reliquefying apparatus according to any one of claims 1 to 3.

5. An LNG supply system comprising:

an LNG tank that stores LNG;
 a compressor that compresses BOG sent from a second return line such that the BOG has a predetermined pressure;
 a BOG booster that is disposed downstream with respect to the compressor, and pressurizes BOG sent through a BOG line such that the BOG has pressure higher than the predetermined pressure;
 a first line that is branched from a BOG line at a downstream position with respect to the BOG booster;
 a first heat exchanger for heat-exchanging the BOG having the pressure;
 a first return line that is branched from the first line in the first heat exchanger, and joins the BOG line at an upstream position with respect to the BOG booster;
 an expander that is disposed in the first return line, and expands BOG which passes through a part of the first heat exchanger;
 a booster that is disposed in the first return line, pressurizes BOG expanded by the expander to pass through the first heat exchanger, and is driven by the expander;
 a second heat exchanger for heat-exchanging the BOG from the LNG tank, and the BOG which passes through the first heat exchanger;
 at least one expansion valve for subjecting BOG which passes through the second heat exchanger to free expansion to perform reliquefaction;
 a gas-liquid separator that separates BOG expanded by the expansion valve into BOG and LNG;
 a reliquefaction LNG line for sending LNG from the gas-liquid separator to the LNG tank or a use point;
 a second return line that is branched from the first line at an upstream position with respect to at least the one expansion valve, passes through the second heat exchanger, then passes through a part or a whole of the first heat exchanger, and sends BOG into the compressor; and
 a BOG line that passes through the second heat exchanger from the gas-liquid separator to allow the BOG to join the second return line.

6. The LNG supply system according to claim 5, further comprising at least one expansion valve in the second return line at an upstream position with respect to the second heat exchanger, or upstream with respect to a branch point at which the second return line is branched from the first line and downstream with respect to the second heat exchanger, in the first line.

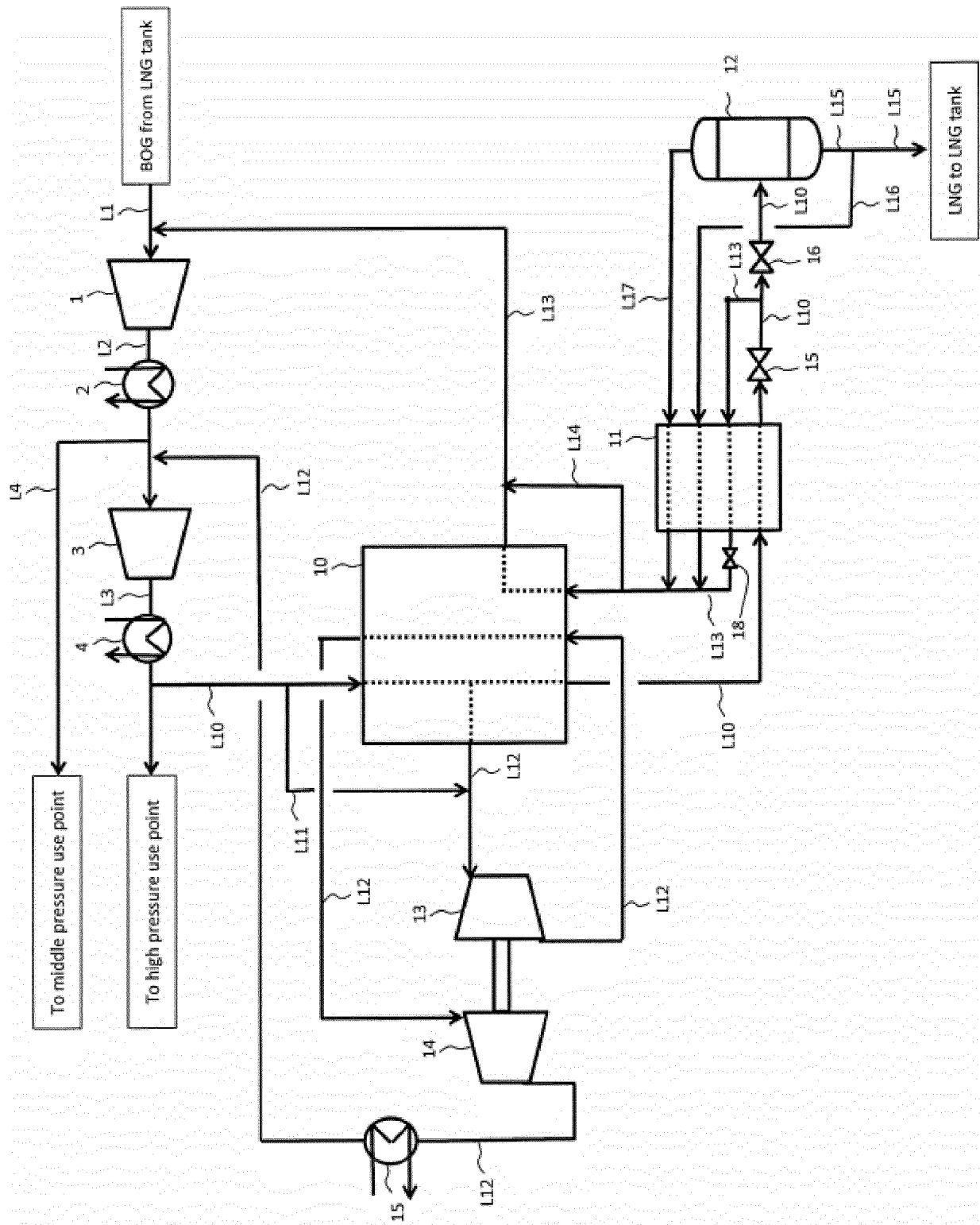


FIG. 1A

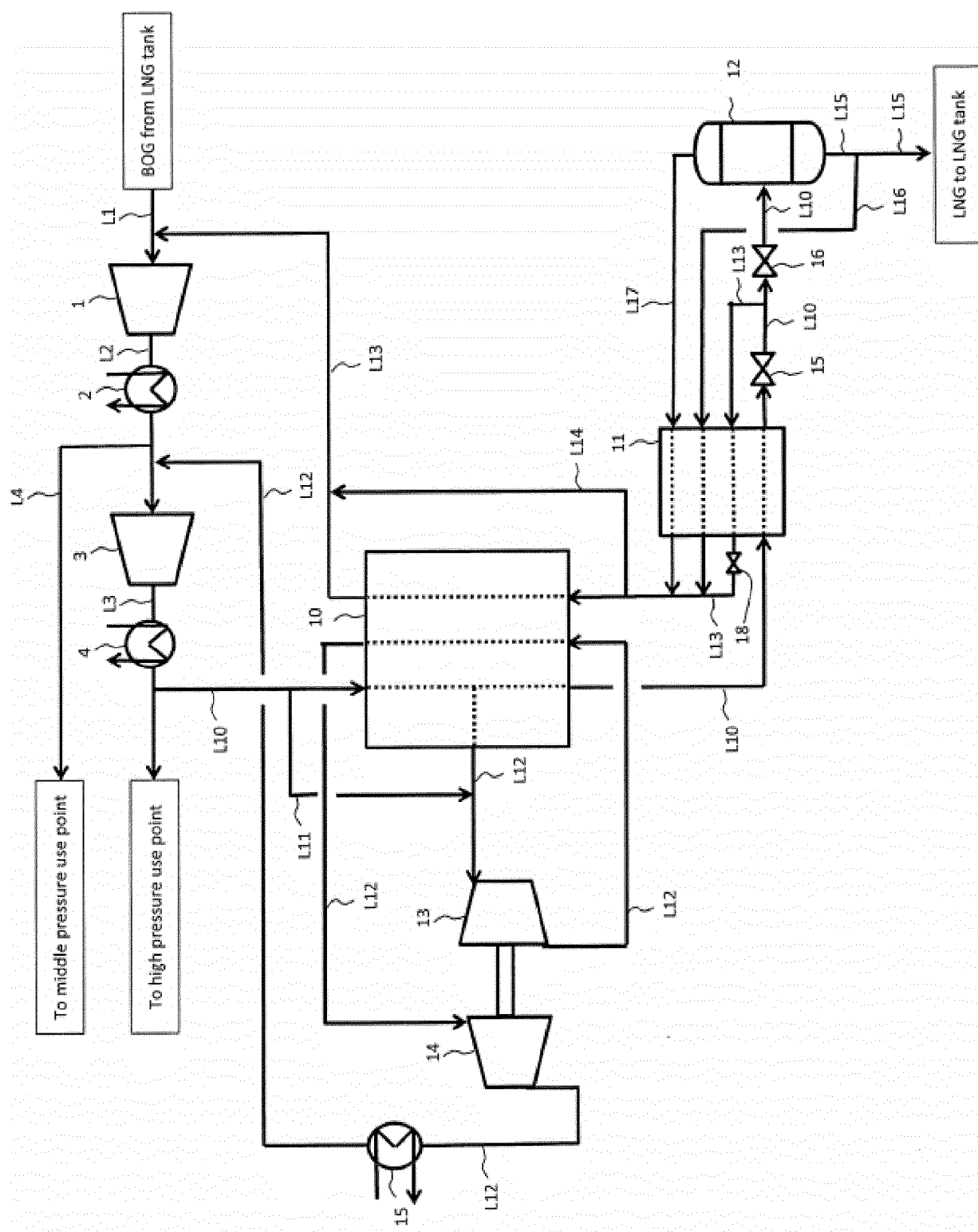


FIG. 1B

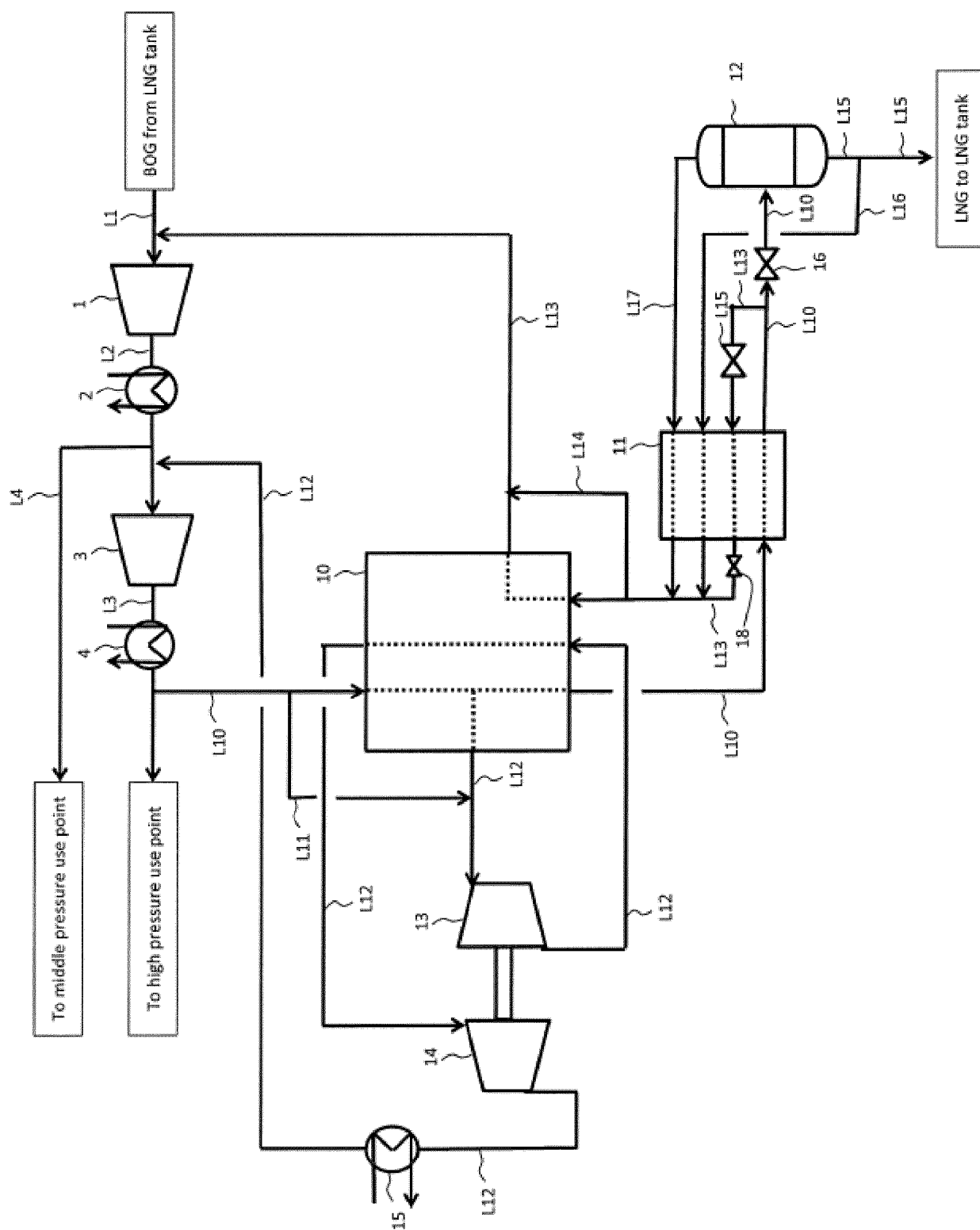


FIG. 1C

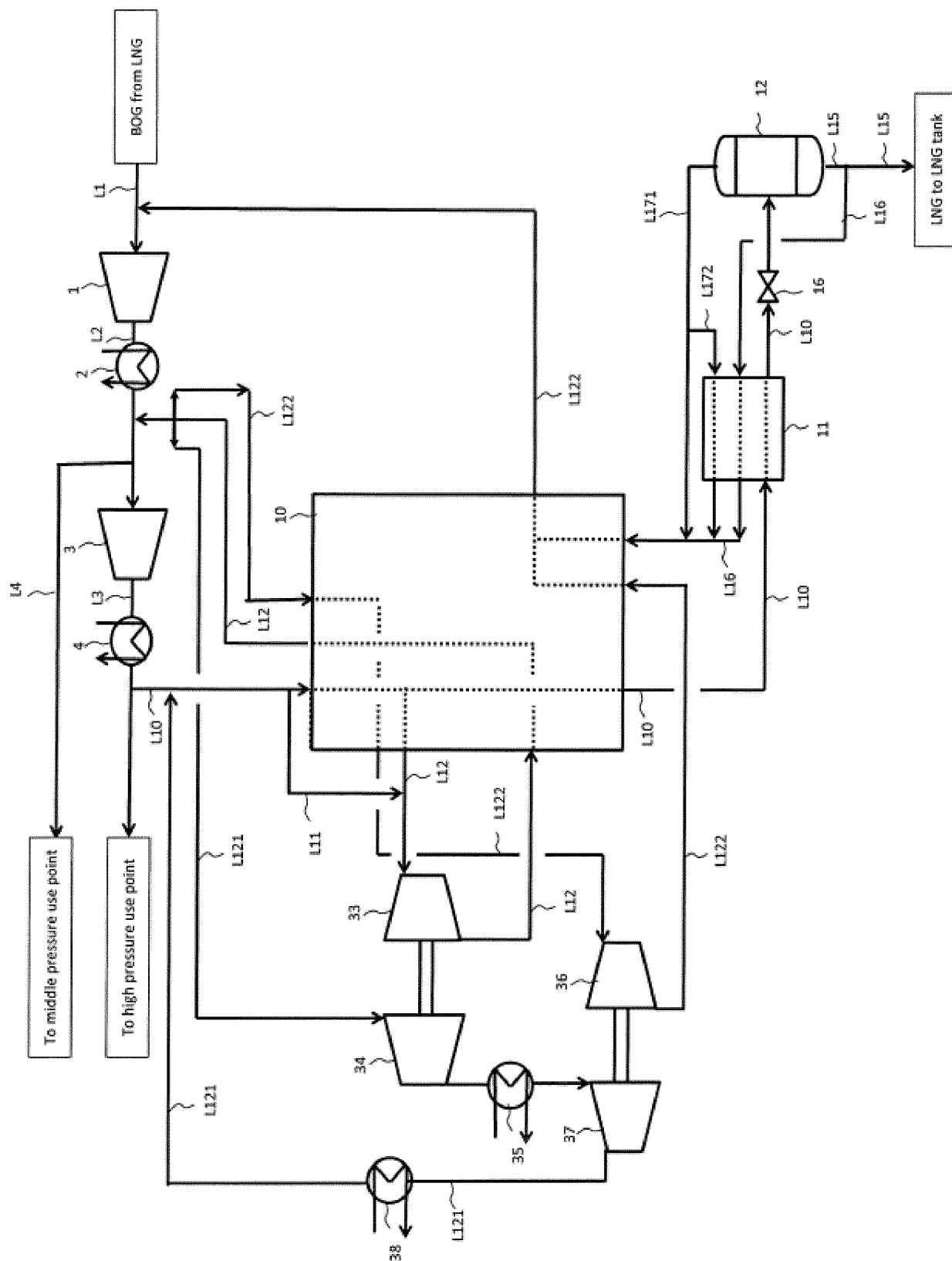


FIG. 2

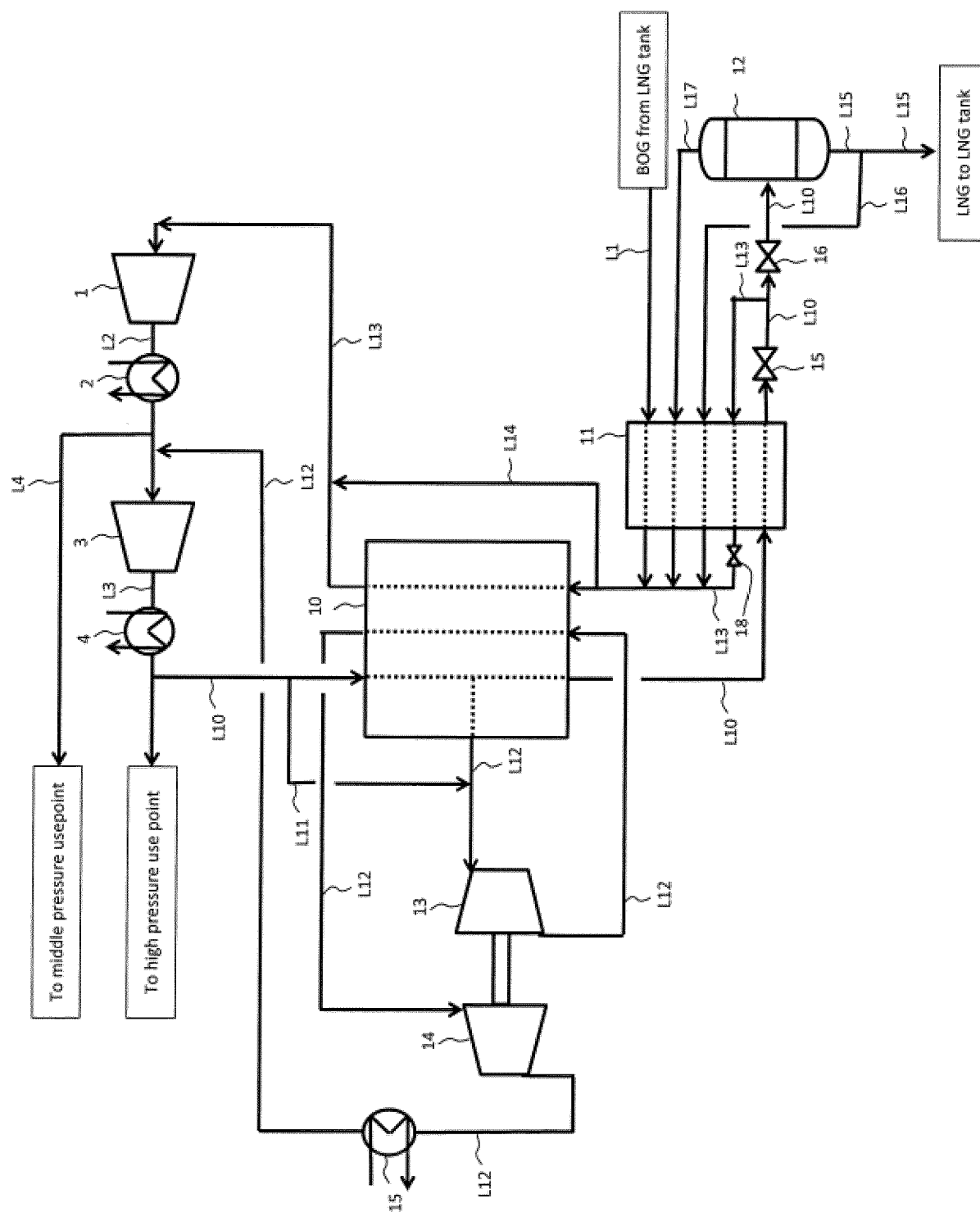


FIG. 3

REFERENCES CITED IN THE DESCRIPTION

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