

Natural gas production apparatus and natural gas production method

The present invention relates to a natural gas production apparatus and a natural gas production method employing liquefied natural gas as a starting material, which are especially useful as a natural gas production apparatus and supply method enabling a reduction in the size of production facilities while a natural gas liquid recovery rate is maintained.

Natural gas (NG) is stored as liquefied natural gas (LNG) for transport and storage convenience etc., and is vaporized before being used mainly for thermal power generation or city gas. Since the shale gas revolution, cheap LNG has become available on the LNG spot market and there are also more and more cases where LNG originating from different countries is used. Furthermore, when NG is used as a power generation fuel, for example, 100% methane is somewhat more convenient for increasing combustion energy to achieve increased power generation. On the other hand, components having a large carbon number, such as ethane (also referred to below as “components such as ethane”), are not only valuable as a starting material in chemical plants, they are also used as high-calorie LNG and thereby also have the advantage of enabling a reduction in the amount of liquid propane gas (LPG) used. In light of this situation, there is a need to provide a highly energy-efficient process for separating LNG into the methane-rich gas NG, and components such as ethane, in locations where LNG is consumed (LNG receiving terminals).

A technique for extracting natural gas liquid (NGL) from LNG to supply NG is intended to adjust the calorific value of fuel gas supplied mainly to power stations and pipelines. In Patent Document 1, for example, this aim is achieved by extracting the components having a large carbon number such as ethane from starting material LNG, and supplying NG with a high methane concentration. All of the LNG which has been boosted to a supply pressure is supplied to a distillation column, and NG with a high methane concentration is produced from the column top while NGL is recovered from the column bottom.

Prior Art Documents**Patent Documents**

Patent Document 1 : JP 2016-156581 A

Summary of the Invention

Problem to be Solved by the Invention

- 5 Apparatuses for supplying large quantities of NG intended for power generation or pipeline supply process huge amounts of LNG, and therefore the equipment has to be very large. Distillation columns in particular are operated under a high pressure (e.g., 1.5-4 MPaA), so the distillation column installation costs are very high given the large size.
- 10 Furthermore, techniques for extracting NGL from LNG to supply NG are intended to adjust the calorific value of the NG supplied as a fuel gas and do not necessarily require complete extraction of the components having a large carbon number such as ethane from the starting material LNG. Despite this, it is very inefficient to perform precision distillation to maintain the recovery rate of higher components
- 15 such as ethane.
- In light of this situation, the present invention provides a natural gas supply apparatus and supply method which make it possible to supply NG having a desired calorific value while the recovery rate of NGL is maintained, without the size of a distillation column being increased.

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Means for Solving the Problem

(Invention 1)

- A natural gas production apparatus according to the present invention extracts natural gas liquid from liquefied natural gas to produce natural gas, and comprises:
- 25 a starting material supply flow path (102) for introducing a liquefied natural gas starting material into a first liquefied natural gas heater (11);
- a separator (12) for separating, into a liquid phase and a gas phase, a gas/liquid mixed fluid drawn from the first liquefied natural gas heater (11);
- a low-boiling-point component supply flow path (111) for delivering, as the
- 30 natural gas, a vapor component in the gas phase drawn from the separator (12);
- a high-boiling-point component supply flow path (105) for introducing a liquid component in the liquid phase drawn from the separator (12) into a distillation column (7) in a gaseous and/or liquid state;

a first reflux flow path (104) for introducing at least a portion of a methane-rich vapor component drawn from a column top portion of the distillation column (7) into the distillation column (7) as a first reflux liquid;
a first natural gas delivery flow path (103) for delivering, as the natural gas, at least
5 a portion of the methane-rich vapor component drawn from the column top portion of the distillation column (7) which is not introduced into the first reflux flow path (104); and
a natural gas liquid delivery flow path (113) for delivering, as the natural gas liquid,
a liquid component drawn from the column bottom portion of the distillation
10 column (7).

The liquefied natural gas is heated to a predetermined temperature in the first liquefied natural gas heater (11). Here, methane, which is a low-boiling-point component contained in the liquefied natural gas, is vaporized, thereby producing a gas/liquid mixed state. The liquefied natural gas in the gas/liquid mixed state is
15 separated by the separator (12) into a gas phase and a liquid phase.

At least a portion of the methane contained in the liquefied natural gas is separated into the gas phase by the gas/liquid separation in the separator (12). The vapor component in the gas phase comprises a larger amount of methane, which is a low-boiling-point component, than the liquid component in the liquid phase. The vapor
20 component in the gas phase may be a vapor in its entirety, but a liquid component which is not vaporized may also be present as a part thereof.

Meanwhile, the hydrocarbon components having a larger carbon number than methane are separated in the liquid phase together with the methane that was not separated in the gas phase because the boiling points differ greatly from that of
25 methane and the concentration in the liquefied natural gas is low.

The liquid component in the liquid phase comprises hydrocarbon components having a larger carbon number than methane (e.g., higher hydrocarbon components such as ethane) and methane which was not separated in the gas phase.

The methane separated in the gas phase by the separator is delivered as product
30 natural gas without further treatment because the content of the higher hydrocarbon components such as ethane is sufficiently low. When there is no need for high-purity methane as the product natural gas, the present invention is especially advantageous in that it is possible to supply natural gas having methane as the main component thereof without implementing precision distillation.

Meanwhile, the liquefied natural gas containing the higher hydrocarbon components such as ethane separated in the liquid phase by the separator (12) is supplied to an intermediate portion of the distillation column (7) (a portion of the distillation column positioned below a top portion and above the column bottom portion). A methane-rich gas is separated from the column top portion of the distillation column (7), and natural gas liquid containing the higher hydrocarbon components such as ethane is separated from the column bottom portion.

The natural gas liquid supplied to the distillation column (7) has a predetermined amount of the methane component removed therefrom by the separator (12), so the separation can be implemented using a smaller distillation column than when the methane component is not removed. That is to say, it is possible to reduce the size of the distillation column (7) by utilizing the separator (12).

It should be noted that in the present specification, liquefied natural gas is the starting material and natural gas liquid is the product comprising a large amount of components having a higher boiling point than methane which are extracted from the liquefied natural gas starting material.

When the liquefied natural gas starting material is vaporized and supplied in an unmodified form, without being separated, fluctuations in the composition of the liquefied natural gas starting material are directly reflected in the composition of the vaporized natural gas, so there is a problem in that the composition of the product natural gas is unstable. In contrast to this, according to the present invention, the methane concentration of the gas separated on the gas phase side by the separator (12) can be adjusted in accordance with the operating temperature of the separator, even if the concentration of the higher hydrocarbon components such as ethane contained in the liquefied natural gas starting material fluctuates. Furthermore, it is also possible to achieve a constant methane concentration in the natural gas obtained by distillation in the distillation column (7) of the liquid component separated on the liquid phase side by the separator (12). Accordingly, the present invention makes it possible to supply natural gas having a predetermined and stable methane concentration even if the composition of the liquefied natural gas starting material fluctuates.

In addition, according to the present invention, it is possible to control the methane concentration of the product natural gas by adjusting the operating temperature and/or pressure of the first liquefied natural gas heater (11). That is to say, the

methane concentration of the product natural gas has an inversely proportional relationship with the operating temperature of the first liquefied natural gas heater (11). When the temperature of the first liquefied natural gas heater (11) is high, the methane concentration decreases because the product natural gas contains a larger amount of high-boiling-point components. When the temperature of the first liquefied natural gas heater (11) is low, the methane purity increases because the product natural gas contains fewer high-boiling-point components. In the same way, when the pressure of the first liquefied natural gas heater (11) is low, the methane concentration decreases because the product natural gas contains a larger amount of high-boiling-point components having a low vapor pressure. When the pressure in the first liquefied natural gas heater (11) is high, the methane concentration increases because the product natural gas contains fewer high-boiling-point components.

The pressure of the fluid introduced into the first liquefied natural gas heater (11) is less than the pressure of the liquefied natural gas stored in the starting material supply (101). For example, the pressure of the fluid introduced into the first liquefied natural gas heater (11) may be between 0.2 times and 0.99 times the pressure of the liquefied natural gas stored in the starting material supply (101).

The operating temperature of the first liquefied natural gas heater (11) is equal to or greater than the boiling point of methane at the pressure of the fluid introduced into the first liquefied natural gas heater (11), and may be controlled to a temperature equal to or less than the boiling point of the high-boiling-point components (e.g., ethane etc.) having a higher boiling point than methane. When the temperature in the first liquefied natural gas heater (11) is close to the boiling point of methane, the methane concentration in the product natural gas increases. When the temperature in the first liquefied natural gas heater (11) is close to the boiling point of the high-boiling-point components, a larger amount of the high-boiling-point components is mixed in with the product natural gas, and the methane concentration decreases accordingly.

It is thus possible to supply natural gas having the desired calorific value by adjusting the methane concentration of the product natural gas.

(Invention 2)

The abovementioned natural gas production apparatus may comprise:

- a first vaporizer (3) for vaporizing the liquid component in the liquid phase drawn from the separator (12);
 - 5 a first expansion turbine (4) for expanding the gas drawn from the first vaporizer (3);
 - a first heat exchanger (1) for performing heat exchange between the liquefied natural gas starting material and the methane-rich vapor component;
 - a second heat exchanger (2) for performing heat exchange between a gas drawn
10 from the first expansion turbine (4) and liquefied natural gas drawn from the first heat exchanger (1); and
 - a first compressor (5) disposed in the first natural gas delivery flow path (103), and the gas drawn from the first vaporizer (3) may be introduced into an intermediate portion of the distillation column (7) via the first expansion turbine
15 (4) and the second heat exchanger (2),
 - at least a portion of the methane-rich vapor component may be introduced into an upper portion of the distillation column (7) via the first heat exchanger (1), and
 - at least a portion of the methane-rich vapor component which is not introduced into the distillation column (7) may be delivered from the first natural gas delivery
20 flow path (103) as the natural gas, via the first compressor (5).
- The liquefied natural gas from which cold is released in the first heat exchanger (1) and the second heat exchanger (2) is further heated to a predetermined temperature in the first liquefied natural gas heater (11). Furthermore, the gas drawn from the first vaporizer (3) is cooled by means of heat exchange with the liquefied natural
25 gas starting material in the second heat exchanger (2). The cooled gas is introduced into the intermediate portion of the distillation column (7) as a reflux liquid.

(Invention 3)

- In the abovementioned natural gas production apparatus, the methane-rich vapor
30 component drawn from the column top portion of the distillation column (7) may be cooled in the first heat exchanger (1).
- In the abovementioned natural gas production apparatus, the methane-rich vapor component drawn from the column top portion in the column top portion of the distillation column (7) may be introduced into an independent condenser where a

portion thereof may be liquefied, and may then be supplied to the upper portion of the distillation column (7). Furthermore, the methane-rich vapor component may also be cooled in the first heat exchanger (1) and at least a portion thereof may be liquefied, and it may then be supplied to the upper portion of the distillation column (7) as a reflux liquid. It is also possible to provide a condenser in order to form the methane-rich vapor component into a reflux liquid, but if the reflux liquid is obtained by liquefaction using the first heat exchanger (1), then the cold of the liquefied natural gas starting material can be efficiently utilized. Furthermore, the liquefied natural gas starting material is heated by means of heat exchange with the methane-rich vapor component in the first heat exchanger (1), so the temperature thereof is raised and it is possible to reduce the load on the first liquefied natural gas heater.

(Invention 4)

In the abovementioned natural gas production apparatus, the first compressor (5) and the first expansion turbine (4) may be independent of each other. Furthermore, an axial end of the first compressor (5) may be connected to an axial end of the first expansion turbine (4). By connecting an axial end of the first compressor (5) and an axial end of the first expansion turbine (4), it is possible to use motive power recovered by the first expansion turbine as motive power for the first compressor, so the natural gas production apparatus can achieve higher energy efficiency.

(Invention 5)

In the abovementioned natural gas production apparatus, the liquefied natural gas starting material may be introduced into the first heat exchanger (1) in a supercooled state and a pressurized state.

(Invention 6)

The abovementioned natural gas production apparatus may also comprise a second compressor (119) which is disposed at a stage after the first compressor (5) and serves to further boost the pressure of the natural gas drawn from the first compressor (5). The pressure of the natural gas drawn from the first compressor (5) may be further raised by means of the second compressor (119), in accordance

with the required pressure of the natural gas delivered from the first natural gas delivery flow path (113).

(Invention 7)

5 The abovementioned natural gas production apparatus may further comprise an expansion mechanism (114; 118) which is disposed in the starting material supply path (102) and serves to expand the liquefied natural gas.

The critical pressure of the liquefied natural gas is approximately 4.6 MPaA and the critical temperature thereof is approximately -83°C. The liquefied natural gas
10 starting material is therefore in a supercritical state when the pressure thereof is above the critical pressure. In the supercritical state, gas/liquid separation cannot be performed by the separator (12). Here, it is possible to perform gas/liquid separation in the separator (12) if the pressure of the liquefied natural gas is reduced to below the critical pressure thereof by providing an expansion
15 mechanism at the stage before the separator (12) to expand the liquefied natural gas in a supercritical state.

(Invention 8)

An expansion valve (114) or an expander (118) may be used as the expansion
20 mechanism (114; 118) in the abovementioned natural gas production apparatus.

(Invention 9)

The abovementioned natural gas production apparatus may further comprise:
a third heat exchanger (115) for heating the liquefied natural gas in a gaseous
25 and/or liquid state drawn from the expansion mechanism (114; 118) and introducing same into the first liquefied natural gas heater (11);
a pump (116) for compressing the vapor component drawn from a gas phase portion of the separator (12) to the low-boiling-point component supply flow path (111), after said vapor component has been condensed in the third heat exchanger
30 (115); and
a second vaporizer (117) for vaporizing the natural gas in a liquid state drawn from the pump (116).

The third heat exchanger (115) is disposed at a stage before the separator (12) and after the expansion mechanism (114; 118). The third heat exchanger (115)

performs heat exchange between the liquefied natural gas starting material drawn from the expansion mechanism (114; 118), and the natural gas drawn from the gas phase portion of the separator (12). The temperature of the liquefied natural gas starting material drawn from the expansion mechanism (114; 118) is raised as a result. Meanwhile, the temperature of the natural gas drawn from the gas phase portion of the separator (12) decreases and the natural gas condenses.

The condensed natural gas is in a liquid state and the pressure thereof is boosted by means of the pump (116), after which said condensed natural gas is vaporized in the second vaporizer (117). The vaporized natural gas may be merged in the first natural gas delivery flow path (103) and may be supplied as product natural gas.

(Invention 10)

When the second expander (118) is provided as the expansion mechanism (114; 118) in the abovementioned natural gas production apparatus, an axial end of the second expander (118) may be connected to an axial end of the second compressor (119).

It is possible to use motive power recovered by the second expander (118) as motive power for the second compressor (119), so it is possible to achieve greater energy efficiency.

(Invention 11)

A natural gas production method according to the present invention is a method in which natural gas liquid is extracted from liquefied natural gas to produce natural gas, and comprises the following steps (1) to (5):

- (1) a gas/liquid separation step in which a portion of the cold of the liquefied natural gas starting material is released, after which the liquefied natural gas is separated into a gas phase and a liquid phase;
- (2) a first natural gas extraction step in which a vapor component separated in the gas/liquid separation step is extracted as product natural gas;
- (3) a distillation step in which a liquid component separated in the gas/liquid separation step is distilled;
- (4) a second natural gas extraction step in which at least a portion of the vapor component drawn from a column top portion of a distillation column in the distillation step is extracted as product natural gas; and

(5) a natural gas liquid extraction step in which a liquid component drawn from a column bottom portion of the distillation column is extracted as the natural gas liquid.

5 In the gas/liquid separation step, a portion of the cold is released and a portion of the liquefied natural gas starting material is vaporized. In the gas/liquid separation step, after a portion of the cold has been released, the liquefied natural gas may be introduced into a natural gas heater, for example, and heated, and may be further vaporized.

10 As a result of the heating, methane which is a low-boiling-point component contained in the liquefied natural gas is vaporized so that the liquefied natural gas starting material is in a gas/liquid mixed state. The liquefied natural gas which is in a gas/liquid mixed state is introduced into the separator, for example, and is thereby separated into a gas phase and a liquid phase. By separating the gas phase and the liquid phase, at least a portion of the methane contained in the liquefied
15 natural gas is separated in the gas phase. Meanwhile, the hydrocarbon components higher than methane, such as ethane, are separated in the liquid phase together with methane which was not separated in the gas phase because the boiling points differ greatly from that of methane and the concentration in the liquefied natural gas is low.

20 In the first natural gas extraction step, the vapor component separated in the gas phase by the separator, for example, is mainly formed by methane and is delivered as product natural gas without further treatment because the content of higher hydrocarbon components such as ethane is sufficiently low. When there is no need for high-purity methane as the product natural gas, the present invention is
25 especially advantageous in that it is possible to supply natural gas having methane as the main component thereof without implementing precision distillation.

Meanwhile, the liquefied natural gas containing the higher hydrocarbon components such as ethane which is a liquid component separated in the liquid phase by the separator, for example, is vaporized in the distillation step and
30 expanded and cooled, after which it is distilled in the distillation column. By means of the distillation, the gas is separated into methane and natural gas liquid containing higher hydrocarbon components such as ethane. The gas vaporized after separation into the liquid phase in the gas/liquid separation step is cooled by the

cold released in a starting material liquefied natural gas introduction step, and then introduced into the distillation column.

The natural gas liquid supplied to the distillation column has a predetermined amount of the methane component removed therefrom by the separator, for example, so the separation can be implemented using a smaller distillation column than when the methane component is not removed.

When the liquefied natural gas starting material is vaporized and supplied in an unmodified form, without being separated, fluctuations in the composition of the liquefied natural gas starting material are directly reflected in the composition of the vaporized natural gas, so there is a problem in that the composition of the product natural gas is unstable. In contrast to this, according to the present invention, the methane concentration of the gas separated on the gas phase side by the separator, for example, can be adjusted in accordance with the separation temperature, even if the concentration of the higher hydrocarbon components such as ethane contained in the liquefied natural gas starting material fluctuates. Furthermore, it is also possible to achieve a constant methane concentration in the natural gas obtained by distillation in the distillation column of the liquid component separated on the liquid phase side by the separator, for example. Accordingly, the present invention makes it possible to supply natural gas having a predetermined and stable methane concentration even if the composition of the liquefied natural gas starting material fluctuates.

(Invention 12)

In the abovementioned method for producing natural gas, at least a portion of the vapor component drawn from the column top portion of the distillation column may be introduced into the distillation column as a reflux liquid after having been cooled by means of heat exchange with the liquefied natural gas starting material.

A portion of the vapor component drawn from the column top portion of the distillation column may also be cooled and liquefied by means of an independent condenser provided in the distillation column, but it may equally be cooled and liquefied by means of heat exchange with the liquefied natural gas starting material. As a result of being cooled, the vapor component is cooled and at least a portion thereof is liquefied and supplied to the upper portion of the distillation column as a reflux liquid. If the reflux liquid is formed by means of liquefaction by heat

exchange with the liquefied natural gas starting material, then the cold of the liquefied natural gas can be efficiently utilized. Furthermore, the liquefied natural gas starting material is heated by means of heat exchange with the methane-rich vapor component in the first heat exchanger, so the temperature thereof is raised
5 and it is possible to reduce the load on the first liquefied natural gas heater.

(Invention 13)

In the second natural gas extraction step according to the abovementioned method for producing natural gas, the natural gas may be delivered after the pressure
10 thereof has been boosted.

By using a compressor or the like, it is possible to supply natural gas having a desired pressure by supplying the natural gas after the pressure thereof has been boosted to any pressure.

15 (Invention 14)

In the gas/liquid separation step according to the abovementioned method for producing natural gas, at least a portion of the liquefied natural gas may be separated into a gas phase and a liquid phase after having been heated to a temperature equal to or greater than the boiling point of methane and equal to or
20 less than the boiling point of ethane.

According to the present invention, it is possible to control the methane concentration in the product natural gas by adjusting the temperature of the liquefied natural gas separated into a gas phase and a liquid phase. The liquefied natural gas starting material mainly contains methane and higher hydrocarbon
25 components such as ethane, but it is possible to raise the methane concentration if the temperature of the liquefied natural gas separated into the gas phase and the liquid phase is reduced. It is likewise possible to reduce the methane concentration if the temperature of the liquefied natural gas separated into the gas phase and the liquid phase is increased. The temperature of the liquefied natural gas introduced
30 into the separator is between -100°C and -50°C, and preferably between -80°C and -60°C, for example.

The boiling point of ethane is -89°C at atmospheric pressure, but the partial pressure is up to 0.6 MPaA when LNG at 4 MPaA, for example, is treated by the

separator, and the boiling point becomes approximately -50°C in the present invention.

(Invention 15)

- 5 The abovementioned method for producing natural gas may further comprise a starting material expansion step in which the pressure of the liquefied natural gas starting material supplied to the gas/liquid separation step is reduced to a pressure no greater than the critical pressure of liquefied natural gas.
- When the liquefied natural gas starting material is in a supercritical state,
- 10 gas/liquid separation cannot be performed. An expansion step may therefore be provided in order to reduce the pressure of the liquefied natural gas starting material to below a supercritical pressure when said liquefied natural gas starting material is in a supercritical state. The liquefied natural gas starting material will no longer be in a supercritical state as a result, and it is possible to perform
- 15 gas/liquid separation.

Brief Description of the Drawings

- Fig. 1 shows a configuration example of a natural gas production apparatus according to Mode of Embodiment 1.
- 20 Fig. 2 shows a configuration example of a natural gas production apparatus according to a different Mode of Embodiment 2.
- Fig. 3 shows a configuration example of a natural gas production apparatus according to a different Mode of Embodiment 3.
- Fig. 4 shows a configuration example of a natural gas production apparatus
- 25 according to a different Mode of Embodiment 4.
- Fig. 5 illustrates demonstration results in a configuration example of the natural gas production apparatus according to Mode of Embodiment 1.
- Fig. 6 shows a configuration example of a natural gas production apparatus according to Mode of Embodiment 2.
- 30 Fig. 7 shows a configuration example of a natural gas production apparatus according to Mode of Embodiment 3.
- Fig. 8 shows a configuration example of a natural gas production apparatus according to Mode of Embodiment 4.

Mode of Embodiment of the Invention

Several modes of embodiment of the present invention will be described below. The modes of embodiment described below illustrate examples of the present invention. The present invention is in no way limited to the following modes of embodiment and also includes a number of variant examples implemented within a scope that does not alter the essential point of the present invention. It should be noted that there is no limitation in terms of all of the constituent elements described below being constituent elements which are essential to the present invention.

- 5 A natural gas production method in which natural gas liquid is extracted from liquefied natural gas to produce natural gas in accordance with the present invention will be described with the aid of fig. 1.

Gas/liquid separation step

- 15 The gas/liquid separation step is a step in which a liquefied natural gas starting material is separated into a gas phase and a liquid phase by means of a separator 12. The liquefied natural gas is stored in a starting material supply 101 in a supercooled and pressurized state (e.g., a temperature of between -165°C and -130°C , and a pressure of between 2 MPaA and 5 MPaA). The liquefied natural gas may be introduced directly into a first liquefied natural gas heater 11, as shown in fig. 6, but it may also have a portion of the cold removed therefrom by passage through a heat exchanger (first heat exchanger 1 and second heat exchanger 2) before being introduced into the first liquefied natural gas heater 11, as shown in fig. 1.
- 25 Specifically, the liquefied natural gas is first of all supplied from the starting material supply 101 to the first heat exchanger 1. Cold is released in the first heat exchanger 1 as a result of heat exchange with a vapor component drawn from a column top portion of a distillation column 7 which will be described later.
- The liquefied natural gas is then introduced from the first heat exchanger 1 into the second heat exchanger 2. Cold is further released in the second heat exchanger 2 as a result of heat exchange with a vapor component that has passed through a first expander which will be described later.
- 30 The liquefied natural gas which has passed through the second heat exchanger 2 is in a state in which the temperature thereof is higher than that of the liquefied

natural gas stored in the starting material supply. The liquefied natural gas is introduced into the first liquefied natural gas heater 11 and is further heated to a desired temperature, and a gas/liquid mixed state is produced. The desired temperature is equal to or greater than the boiling point of methane and equal to or less than the boiling point of ethane, for example, and it may be a temperature of between -100°C and -50°C, preferably between -80°C and -60°C, for example. The heating temperature afforded by the first liquefied natural gas heater is determined in accordance with the composition and pressure etc. of the liquefied natural gas.

10 The liquefied natural gas in a gas/liquid mixed state is separated into a gas phase and a liquid phase in the separator 12.

First natural gas extraction step

The first natural gas extraction step is a step in which the vapor component separated in the gas phase in the separator 12 is extracted as natural gas. Methane is mainly separated in the gas phase by the separator 12. The vapor component in the gas phase may be supplied without further treatment as product natural gas. When the temperature of the natural gas supplied is lower than the usage temperature, the natural gas may be supplied once it has been heated by providing a second liquefied natural gas heater (indicated by 6 in fig. 4) at a stage after the separator.

Distillation step

The distillation step is a step in which the liquid component separated in the liquid phase in the separator 12 is introduced into the distillation column 7, and the liquid component is distilled in the distillation column 7. Before the liquid component in the liquid phase is introduced into the distillation column 7, it may be vaporized by heating and expanded/cooled, after which it may be further cooled. In fig. 1, a first vaporizer 3 is provided at a stage after the separator 12 in order to vaporize the liquid component in the liquid phase, and an expansion turbine 4 is used for expansion/cooling. After this, the material is cooled by heat exchange in the second heat exchanger 2 with the liquefied natural gas starting material, and introduced into the distillation column 7 in a partially liquefied state. The low-boiling-point component mainly comprising methane is separated in the upper

region of the distillation column 7, and the high-boiling-point components such as ethane are separated in the lower region.

- A portion of the low-boiling-point component (methane-rich vapor component) (e.g., between 5% and 95% of the methane-rich vapor component) separated in the
- 5 column top portion of the distillation column 7 in the distillation step may be condensed and returned to the column top portion of the distillation column 7 as a first reflux liquid. Here, the methane-rich vapor component may be condensed by being introduced into the first heat exchanger 1 and undergoing heat exchange with the liquefied natural gas starting material.
- 10 A reboiler (not depicted) may be provided in order to heat a portion of the natural gas liquid extracted from the column bottom portion of the distillation column 7, and to return this portion to the column bottom portion of the distillation column 7.

Second natural gas extraction step

- 15 The second natural gas extraction step is a step in which at least a portion of the vapor component drawn from the column top portion of the distillation column 7 is extracted as natural gas. The natural gas may be compressed by means of a first compressor 5 to boost the pressure thereof, and supplied as a product. The portion of the vapor component drawn from the column top portion of the distillation
- 20 column 7 which is not delivered as natural gas is condensed and returned to the distillation column 7 as a reflux liquid. Here, the vapor component may be condensed by means of a condenser, but it may also be condensed by undergoing heat exchange with the liquefied natural gas starting material. In fig. 1, heat exchange is performed between the vapor component and liquefied natural gas in
- 25 the first heat exchanger 1.

- As shown in fig. 2, the vapor component drawn from the column top portion of the distillation column 7 and the liquefied natural gas starting material may undergo heat exchange in the first heat exchanger 1 and a portion thereof may be liquefied. In this case, a second separator 201 is provided at a stage after the first heat
- 30 exchanger 1 in order to separate the materials into a gas phase and a liquid phase, and only the vapor component in the gas phase may be delivered as natural gas.

As shown in fig. 3, the vapor component (indicated by A in fig. 3) may be branched at the column top portion of the distillation column 7, with a portion thereof (indicated by C in fig. 3) being returned to the distillation column 7 via the

first heat exchanger 1 and another portion thereof (indicated by B in fig. 3; e.g., between 5% and 95% of the methane-rich vapor component A) being delivered as natural gas.

5 Natural gas liquid extraction step

The natural gas liquid extraction step is a step in which the liquid component drawn from the column bottom portion of the distillation column 7 is extracted as natural gas liquid. The liquid component contains a large amount of high-boiling-point components such as ethane.

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Starting material expansion step

The starting material expansion step is a step in which the liquefied natural gas starting material is expanded in such a way that the pressure thereof is reduced to below a supercritical pressure when said liquefied natural gas starting material is in a supercritical state (a state in which the pressure is equal to or greater than the supercritical pressure). The pressure of the liquefied natural gas starting material is reduced to a pressure lower than approximately 4.6 MPaA, which is the critical pressure of liquefied natural gas, by means of expansion employing an expansion mechanism (e.g., an expansion valve or expander).

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Mode of Embodiment 1

A natural gas production apparatus according to Mode of Embodiment 1 will be described with the aid of fig. 1.

25 The liquefied natural gas starting material is stored in the starting material supply 101. The liquefied natural gas is in a supercooled and pressurized state, the temperature of liquefied natural gas being in a range of between -165°C and -130°C, and the pressure being in a range of between 2 MPaA and 5 MPaA, for example.

30 The first heat exchanger 1 performs heat exchange between the liquefied natural gas starting material and the methane-rich vapor component drawn from the column top portion of the distillation column 7. The temperature of the liquefied natural gas is raised from 1°C to around 10°C, for example, in the first heat exchanger 1. The apparatus is arranged in such a way that part or all of the

liquefied natural gas drawn from the first heat exchanger 1 and the starting material supply 101 is introduced.

The second heat exchanger 2 performs heat exchange between the liquefied natural gas drawn from the first heat exchanger 1 and a gas drawn from the expansion turbine 4 which will be described later. The temperature of the liquefied natural gas is raised from 5°C to around 40°C, for example, in the second heat exchanger 2. The second heat exchanger 2 is arranged at a stage after the first heat exchanger and receives the liquefied natural gas drawn from the first heat exchanger.

The first liquefied natural gas heater 11 further heats the liquefied natural gas that has passed through the first heat exchanger 1 and the second heat exchanger 2, and produces a gas/liquid mixed state. The natural gas liquid may be heated to a temperature equal to or greater than the boiling point of methane and equal to or less than the boiling point of ethane in the first liquefied natural gas heater 11. It may be heated to a temperature of between -100°C and -50°C, for example. The first liquefied natural gas heater 11 is disposed at a stage after the second heat exchanger 2 and receives the liquefied natural gas that has passed through the second heat exchanger 2.

The liquefied natural gas stored in the starting material supply 101 is introduced into the first liquefied natural gas heater 11 by means of the starting material supply flow path 102 which passes through the first heat exchanger 1 and the second heat exchanger 2.

The separator 12 is a separator for separating, into a liquid phase and a gas phase, the liquefied natural gas which has been placed in a gas/liquid mixed state in the first liquefied natural gas heater 11. The separator 12 is disposed at a stage after the first liquefied natural gas heater 11 and receives the whole amount of the liquefied natural gas in a gas/liquid mixed state drawn from the first liquefied natural gas heater 11. The low-boiling-point component having methane as the main component is separated into the gas phase, and the high-boiling-point component comprising methane which was not separated in the gas phase and a large amount of ethane etc. is separated into the liquid phase. By controlling the heating temperature in the first liquefied natural gas heater 11, it is possible to control the separation ratio of the gas phase and liquid phase.

That is to say, when the temperature in the first liquefied natural gas heater 11 is increased, the amount of material separated in the gas phase increases and the

methane concentration in the gas phase decreases. On the other hand, the amount of material separated in the liquid phase decreases and the load in the distillation column 7 is reduced, so distillation can be performed using a small-scale distillation column.

- 5 When the temperature in the first liquefied natural gas heater 11 is reduced, the amount of material separated in the gas phase decreases, but the methane concentration increases. Meanwhile, the amount of material separated in the liquid phase increases, so the load in the distillation column increases and a large-capacity distillation column having a large column diameter is required as a result.
- 10 The vapor component in the gas phase is drawn from the separator 12 via the low-boiling-point component supply flow path 111. The high-boiling-point component constituting the liquid component separated in the liquid phase in the separator 12 is introduced from the separator 12 into the distillation column 7 by means of the high-boiling-point component supply flow path 105 which passes through the first
- 15 vaporizer 3, the first expansion turbine 4, and the second heat exchanger.
- The first vaporizer 3 is a vaporizer for heating and vaporizing the liquid component in the liquid phase separated in the separator 12. The first vaporizer 3 is disposed at a stage after the separator 12 and receives the liquid component in the liquid phase drawn from the separator 12. The temperature in the first vaporizer 3
- 20 is between -5°C and 30°C, for example.
- The first expansion turbine 4 expands and cools the gas drawn from the first vaporizer 3. The first expansion turbine 4 is disposed at a stage after the first vaporizer 3 and receives the whole amount of the gas drawn from the first vaporizer 3. Here, the gas is cooled from 5°C to around 30°C, for example.
- 25 The gas drawn from the first expansion turbine 4 is further cooled by means of heat exchange with the liquefied natural gas starting material in the second heat exchanger 2, after which it is introduced into the distillation column 7.
- The low-boiling-point component having methane as the main component thereof is separated in the upper region of the distillation column 7, and the high-boiling-point components such as ethane are separated in the lower region. At least a
- 30 portion of the methane-rich vapor component separated in the upper region and extracted from the column top portion of the distillation column 7 is cooled and partially liquefied, and is returned to the distillation column 7 via a first reflux flow path 104 as a first reflux liquid. The methane-rich vapor component may be

condensed by a condenser, but it may also be liquefied by heat exchange in the first heat exchanger 1 with the liquefied natural gas starting material.

The portion of the methane-rich vapor component drawn from the column top portion of the distillation column 7 which does not form the first reflux liquid is
5 boosted in pressure by means of the first compressor 5 and delivered as product natural gas via a first natural gas delivery flow path 103.

A natural gas liquid delivery flow path 113 delivers the liquid component drawn from the column bottom portion of the distillation column 7 as natural gas liquid. The natural gas liquid comprises a large amount of high-boiling-point components
10 such as ethane, in addition to methane.

Different Mode of Embodiment 2

As shown in fig. 2, the methane-rich vapor component drawn from the column top portion of the distillation column 7 may pass through the first heat exchanger 1,
15 after which it may be introduced into a second separator 201 disposed at a stage after the first heat exchanger 1, and may be separated into a gas phase and a liquid phase. The vapor component in the gas phase which has been separated is boosted in pressure by way of the first compressor 5, after which it is delivered as natural gas. The liquid component in the liquid phase which has been separated is returned
20 to the distillation column 7 as a reflux liquid.

Different Mode of Embodiment 3

The vapor component forming the first reflux liquid and the vapor component delivered as natural gas may be drawn from the column top portion of the
25 distillation column 7 separately, as shown in fig. 1, but they may equally be drawn from the column top portion of the distillation column 7 and then separated, as shown in fig. 3. In this case, the vapor component drawn from the column top portion (A in fig. 3) is branched in two directions, with one portion (B in fig. 3) being delivered from the first natural gas delivery flow path 103 via the first
30 compressor 5 as natural gas. The other portion (C in fig. 3) is returned to the distillation column 7 via the first reflux flow path 104.

Different Mode of Embodiment 4

When the temperature of the natural gas supplied via the first natural gas delivery flow path 103 is lower than the usage temperature, it may be heated by providing a second natural gas heater 6, as shown in fig. 4. The second natural gas heater 6 is disposed on the first natural gas delivery flow path 103.

Different Mode of Embodiment 5

It should be noted that the axial end of the first expansion turbine 4 and the axial end of the first compressor 5 need not be connected, but they may be connected as shown in fig. 1 and configured in such a way that motive power recovered in the first expansion turbine 4 is utilized by the first compressor 5.

Different Mode of Embodiment 6

A second compressor (not depicted) may further be provided at a stage after the first compressor 5, and the pressure of the natural gas boosted by the first compressor 5 may be further boosted by means of the second compressor.

Mode of Embodiment 2

A natural gas production apparatus 106 according to Mode of Embodiment 2 will be described with the aid of fig. 6. Elements bearing the same reference symbols as those of the abovementioned mode of embodiment have the same function and will therefore not be described.

The liquefied natural gas starting material is introduced into the first liquefied natural gas heater 11 from the starting material supply 101 via the starting material supply flow path 102 and heated to a predetermined temperature. The liquefied natural gas is introduced into the separator 12 in a gas/liquid mixed state. The vapor component separated in the gas phase of the separator 12 is delivered as natural gas from the low-boiling-point component supply flow path 111.

The liquid component separated in the liquid phase of the separator 12 is introduced into an intermediate portion of the distillation column 7. The liquid component may be heated at a stage after the separator 12 and before the distillation column 7, but it need not be heated.

The liquefied natural gas is distilled in the distillation column 7, and the methane-rich vapor component drawn from the column top portion of the distillation

column 7 is condensed via the first reflux flow path 104, after which it is returned to the column top portion of the distillation column 7. A heat exchanger in which the methane-rich vapor component is cooled and condensed may also be provided in the first reflux flow path 104.

- 5 The liquid component is delivered as natural gas liquid from the column bottom portion of the distillation column 7 via the natural gas liquid delivery flow path 113. The whole amount thereof may be extracted as product natural gas liquid from the natural gas liquid delivery flow path, but a portion thereof may be supplied to a reboiler 21 in which it is heated, and then returned to the column
10 bottom portion of the distillation column 7.

Mode of Embodiment 3

A natural gas production apparatus 107 according to Mode of Embodiment 3 will be described with the aid of fig. 7. Elements bearing the same reference symbols as
15 those of the abovementioned modes of embodiment have the same function and will therefore not be described.

The liquefied natural gas starting material is introduced from the starting material supply 101 into the first heat exchanger 1 and the second heat exchanger 2. When the liquefied natural gas drawn from the second heat exchanger 2 is in a
20 supercritical state (e.g., when the pressure of the liquefied natural gas is above the critical pressure thereof), said liquefied natural gas is expanded by means of an expansion mechanism (the expansion mechanism is an expansion valve 114 here) so that the pressure thereof is reduced to no greater than the critical pressure. It is not possible to perform gas/liquid separation when the liquefied natural gas is
25 introduced into the separator 12 in a supercritical state, but the liquefied natural gas which has been placed in a gaseous and/or liquid state by means of the expansion valve 114 can be subjected to gas/liquid separation by means of the separator 12.

The pressure of the liquefied natural gas may be reduced from 8 MPaA to 4 MPaA,
30 for example, by means of the expansion valve 114. Here, the pressure of the liquefied natural gas is lower than the critical pressure thereof, which is 4.6 MPaA, so the liquefied natural gas is no longer in a supercritical state. The liquefied natural gas which has passed through the expansion valve 114 may be heated from -130°C to around -85°C, for example, by means of a third heat exchanger 115. The

liquefied natural gas heated by means of the third heat exchanger 115 is further heated by means of the first liquefied natural gas heater 11, after which it is introduced into the separator 12. The liquefied natural gas is heated from -85°C to around -75°C , for example, by the first liquefied natural gas heater 11.

- 5 The vapor component obtained by gas/liquid separation in the separator 12 and separated in the gas phase is introduced into the third heat exchanger 115 where it undergoes heat exchange with the liquefied natural gas drawn from the expansion valve 114. The vapor component is cooled from -75°C to around -85°C in the third heat exchanger 115, and is thereby condensed and assumes a liquid state. After this,
10 the pressure is boosted by introduction into a pump 116. The pressure may be boosted by the pump 116 from 4 MPaA to around 8 MPaA, for example, depending on the pressure of the product natural gas which is used.
- The natural gas in the liquid state which has been boosted in pressure by means of the pump 116 is heated to a desired temperature (e.g., 10°C) by means of a
15 vaporizer 117, after which it is drawn from the first natural gas delivery flow path 103.

Mode of Embodiment 4

- A natural gas production apparatus 108 according to Mode of Embodiment 4 will
20 be described with the aid of fig. 8. Elements bearing the same reference symbols as those of the abovementioned modes of embodiment have the same function and will therefore not be described.

- The liquefied natural gas starting material is introduced from the starting material supply 101 into the first heat exchanger 1 and the second heat exchanger 2. When
25 the liquefied natural gas drawn from the second heat exchanger 2 is in a supercritical state (e.g., when the pressure of the liquefied natural gas is above the critical pressure thereof), said liquefied natural gas is expanded by means of an expansion mechanism (the expansion mechanism is a second expander 118 here) so that the pressure thereof is reduced to no greater than the critical pressure. It is
30 not possible to perform gas/liquid separation when the liquefied natural gas is introduced into the separator 12 in a supercritical state, but the liquefied natural gas which has been placed in a gaseous and/or liquid state by means of the second expander 118 can be subjected to gas/liquid separation by means of the separator 12.

The pressure of the liquefied natural gas may be reduced from 8 MPaA to 4 MPaA, for example, by means of the second expander 118. The liquefied natural gas which has passed through the second expander 118 may be heated from -130°C to around -85°C, for example, by means of the third heat exchanger 115. The liquefied natural gas heated by means of the third heat exchanger 115 is further heated by means of the first liquefied natural gas heater 11, after which it is introduced into the separator 12. The liquefied natural gas is heated from -85°C to around -75°C, for example, by the first liquefied natural gas heater 11.

A second compressor 119 is provided at a stage after the first compressor 5 and the pressure of the natural gas which has been boosted by the first compressor 5 is further boosted by the second compressor 119. The pressure reached by means of compression in the second compressor 119 may be 8 MPa, depending on the pressure of the product natural gas which is used. The axial end of the second expander 118 and the axial end of the second compressor 119 are connected and motive power recovered by the second expander 118 can be utilized in the second compressor 119.

The natural gas in the liquid state which has been boosted in pressure by means of the pump 116 is heated to a desired temperature (e.g., 10°C) by means of the second vaporizer 117, after which it is drawn from the first natural gas delivery flow path 103.

Exemplary Embodiment 1

A simulation employing the natural gas production apparatus according to Mode of Embodiment 1 was used to verify the pressure (MPaA), temperature (°C), flow rate (kg/h), and composition (wt%) at each portion, when liquefied natural gas having the following composition was supplied as a starting material. The temperature in the first liquefied natural gas heater 11 was set at -75°C.

The composition of the liquefied natural gas starting material was: methane 90 wt%, ethane 5 wt%, propane 3 wt%, isobutane 1 wt%, normal butane 1 wt%, and nitrogen 0.5 wt%.

Results

The results as illustrated in table 1 were obtained for the pressure (MPaA), temperature (°C), flow rate (kg/h), and composition (wt%) at each of the portions

A-K in fig. 5 when liquefied natural gas (-150°C, 4.00 MPaA) was supplied at 427,000 kg/h.

The positions at each portion A-K in fig. 5 are as follows.

The position of A is an outlet of the starting material supply 101.

- 5 The position of B is downstream of the first heat exchanger 1 and upstream of an inlet of the second heat exchanger 2.

The position of C is downstream of the second heat exchanger 2 and upstream of the first liquefied natural gas heater 11.

- 10 The position of D is a gas phase-side outlet of the separator 12, on the separator 12 side on the low-boiling-point component supply flow path.

The position of E is a liquid phase-side outlet of the separator 12, upstream of the first vaporizer 3.

The position of F is downstream of the first vaporizer 3 and upstream of the first expansion turbine 4.

- 15 The position of G is downstream of the first expansion turbine 4, before the second heat exchanger 2 on the high-boiling-point component supply flow path 105.

The position of H is a second heat exchanger 2 outlet side, on the high-boiling-point component supply flow path 105, before the connection with the distillation column 7.

- 20 The position of I is a section at the column top portion outlet of the distillation column 7, upstream of the first compressor 5.

The position of J is a stage after the first compressor 5.

The position of K is a section at the column bottom portion outlet of the distillation column 7, on the natural gas liquid delivery flow path 113.

25

Table 1

	A	B	C	D	E	F	G	H	I	J	K
Pressure (MPaA)	4.00	3.98	3.96	3.95	3.95	3.89	2.31	2.29	2.29	3.95	2.30
Temperature (deg.C)	-150.0	-145.0	-127.3	-75.0	-75.0	18.0	-0.6	-94.0	-103.9	-71.2	34.4
Mass flow (kg/h)	427,000	427,000	427,000	377,695	49,305	49,305	49,305	49,305	25,028	25,028	24,277
Methane (wt %)	89.5	89.5	89.5	94.6	50.7	50.7	50.7	50.7	99.8	99.8	0.0
Ethane (wt %)	5.0	5.0	5.0	3.6	15.5	15.5	15.5	15.5	0.0	0.0	31.4
Propane (wt %)	3.0	3.0	3.0	1.0	18.3	18.3	18.3	18.3	0.0	0.0	37.2
i-Butane (wt %)	1.0	1.0	1.0	0.2	7.5	7.5	7.5	7.5	0.0	0.0	15.2
n-Butane (wt %)	1.0	1.0	1.0	0.1	7.9	7.9	7.9	7.9	0.0	0.0	16.1
Nitrogen (wt %)	0.5	0.5	0.5	0.6	0.1	0.1	0.1	0.1	0.2	0.2	0.0

Exemplary Embodiment 2

A simulation employing the natural gas production apparatus according to Mode of Embodiment 1 was used to verify the separation environment on the gas phase side and the liquid phase side of the separator 12 when the temperature in the first liquefied natural gas heater 11 was varied under the same conditions as in Exemplary Embodiment 1.

Results

The results as illustrated in table 2 were obtained for the separation proportions of the liquid phase and the gas phase, composition, and recovery rate of high-boiling-point components at or above propane and ethane when the temperature in the first liquefied natural gas heater 11 was varied from -45°C to -85°C with liquefied natural gas (-150°C, 4.00 MPaA) being supplied at 427,000 kg/h.

In table 2, the rectification column diameter ratio is the ratio of the column diameter of the distillation column 7 in this exemplary embodiment to the column diameter of the distillation column when the separator 12 is not provided and the whole amount of the liquefied natural gas starting material supplied from the starting material supply 101 is supplied to the distillation column 7. The product methane concentration % indicates the concentration of methane contained in the product natural gas. The ethane recovery rate indicates the proportion of ethane contained in the liquefied natural gas starting material which is recovered in the product natural gas liquid. The propane recovery rate likewise indicates the proportion of propane contained in the liquefied natural gas starting material which is recovered in the product natural gas liquid. The same also applies to the isobutane recovery rate and the normal butane recovery rate.

As shown in table 2, when the temperature in the separator 12 was set at -85°C, virtually no low-boiling-point components such as methane were vaporized, so the whole amount of the liquefied natural gas supplied from the starting material supply 101 flowed into the liquid phase portion of the separator 12 and no vapor component was separated in the vapor phase portion. Accordingly, the whole amount of the liquid component that flowed into the liquid phase portion of the separator 12 was introduced into the distillation column 7 where it was distilled. The amount of liquefied natural gas introduced into the distillation column 7 was

the same as when the separator was not provided, so the column diameter of the distillation column 7 was the same as when the separator was not provided. Accordingly, the rectification column diameter ratio was 1. The product natural gas drawn from the first natural gas delivery flow path 103 was the gas separated from the column top portion of the distillation column 7, and the methane concentration in the product natural gas was therefore 99%. The high-boiling-point components (ethane, propane, isobutane and normal butane; also referred to below as "ethane etc.") were not mixed in with the product natural gas, so the whole amount thereof was extracted as natural gas liquid. The ethane recovery rate, propane recovery rate, isobutane recovery rate and normal butane recovery rate were therefore 1.

When the temperature in the separator 12 was -45°C , the whole amount of the liquefied natural gas starting material flowed into the gas phase portion of the separator 12 and the whole amount thereof was delivered from the first natural gas delivery flow path 103 as product natural gas. No liquid component flowed into the liquid phase portion of the separator 12 so no component was distilled in the distillation column 7 and there was no need for the distillation column, and the rectification column diameter ratio was therefore 0.

When the temperature in the separator 12 was -65°C , the low-boiling-point components in the liquefied natural gas starting material were separated in the gas phase portion of the separator 12, after which they were supplied from the first natural gas delivery flow path 103 as product natural gas, but a fixed amount of the high-boiling-point components (ethane etc.) were separated in the gas phase portion in the separator, so the methane concentration in the product natural gas was 93%. Furthermore, ethane etc. flowed into the natural gas so the recovery rate of ethane etc. recovered in the natural gas liquid decreased.

Table 2

Separator temperature (°C)	Rectification column diameter ratio	Product methane concentration %	Ethane recovery rate	Propane recovery rate	Isobutane recovery rate	Normal butane recovery rate
-45	0.00	90	0.00	0.00	0.00	0.00
-50	0.06	90	0.01	0.06	0.15	0.22
-55	0.10	91	0.04	0.17	0.36	0.48
-60	0.14	92	0.08	0.29	0.54	0.66
-65	0.17	93	0.14	0.43	0.68	0.78
-70	0.22	94	0.22	0.57	0.79	0.86
-75	0.29	95	0.36	0.70	0.86	0.92
-80	0.45	97	0.58	0.84	0.92	0.95
-85	1	99	1	1	1	1

As shown in table 2, it is possible to adjust the methane concentration while achieving a reduction in the size of the distillation column 7 by controlling temperature in the separator 12. When the temperature in the separator 12 was set at -75°C, for example, despite the fact that the diameter of the distillation column 7 was reduced to 30%, the methane concentration could be improved from 90% to 95%.

Key to Symbols

- 1... First heat exchanger
- 2... Second heat exchanger
- 3... First vaporizer
- 5 4... First expansion turbine
- 5... First compressor
- 6... Second natural gas heater
- 7... Distillation column
- 11... First liquefied natural gas heater
- 10 12... Separator
- 100... Natural gas supply apparatus
- 101... Starting material supply
- 102... Starting material supply flow path
- 103... First natural gas delivery flow path
- 15 104... First reflux flow path
- 105... High-boiling-point component supply flow path
- 111... Low-boiling-point component supply flow path
- 113... Natural gas liquid delivery flow path
- 115... Third heat exchanger
- 20 116... Pump
- 117... Second vaporizer
- 118... Second expander
- 119... Second compressor
- 201... Second separator
- 25