A method and system of refining natural gas that improves the quality of liquefied natural gas and enables separation and recovery of hydrocarbons other than methane. The method of refining natural gas containing methane; any other hydrocarbon selected from the group consisting of ethane, ethylene, propane, propylene, n-butane, isobutane, 1-butene, n-pentane, and isopentane; carbon dioxide; and hydrogen sulfide, includes adjusting a pressure and temperature of the natural gas so that the methane is in the gas phase, the other hydrocarbon in the liquid phase, and the carbon dioxide and the hydrogen sulfide in the solid phase, respectively; separating the natural gas, of which the pressure and temperature has been adjusted, into a gas containing the methane and a suspension liquid; and separating the separated suspension liquid into a liquid containing the other hydrocarbon and a solid containing the carbon dioxide and the hydrogen sulfide.
FIG. 1

NATURAL GAS

LNG

GAS

SUSPENSION LIQUID

LIQUID

SOLID

DEPOSITION
<table>
<thead>
<tr>
<th></th>
<th>GASEOUS PHASE</th>
<th>LIQUID PHASE</th>
<th>SOLID PHASE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MELTING POINT</strong></td>
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<tr>
<td>ETHANE</td>
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<td>28</td>
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<td>ETHYLENE</td>
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<td>36.07</td>
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<td>-47.7</td>
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<td>1-BUTENE</td>
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<td>85.5</td>
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<tr>
<td>ISOPENTANE</td>
<td>-160</td>
<td></td>
<td></td>
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<tr>
<td>CARBON DIOXIDE</td>
<td>-78.5 (SUBLIMATION)</td>
<td></td>
<td></td>
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<tr>
<td>HYDROGEN SULFIDE</td>
<td>-85.5</td>
<td></td>
<td></td>
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</table>

**FIG. 2**
FIG. 6

<table>
<thead>
<tr>
<th>COMPOUND</th>
<th>RATIO (%)</th>
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<tbody>
<tr>
<td>METHANE</td>
<td>65</td>
</tr>
<tr>
<td>n-PENTANE</td>
<td>10</td>
</tr>
<tr>
<td>CARBON DIOXIDE</td>
<td>25</td>
</tr>
</tbody>
</table>
FIG. 7

Graph showing the relationship between temperature (°C) and methane purity (%) for different pressures (1 atm, 2 atm, 5 atm, 10 atm, 20 atm). The graph indicates that as temperature decreases, the methane purity increases, with the curves shifting to the right as pressure increases.
FIG. 8

MELTING POINT OF n-PENTANE

MELTING POINT OF HYDROGEN SULFIDE

PRESSURE (atm)

TEMPERATURE (°C)

UPPER LIMIT

LOWER LIMIT
**FIG. 9**

- **Melting Point** of n-Pentane
- **Boiling Point** of Ethylene

![Graph showing the relationship between pressure and temperature for n-Pentane and Ethylene.](Image)

- **Upper Limit**
- **Lower Limit**

**Axes:**
- **Temperature (°C)**
- **Pressure (atm)**

**Temperature Ranges:**
- Melting point of n-Pentane: -160°C to -100°C
- Boiling point of Ethylene: -100°C to -80°C

**Pressure Ranges:**
- 1 atm to 40 atm
FIG. 10

MELTING POINT OF n-PENTANE
BOILING POINT OF ETHYLENE

PRESSURE (atm)

TEMPERATURE (°C)

UPPER LIMIT
LOWER LIMIT

-160 -140 -120 -100 -80
### FIG. 11

<table>
<thead>
<tr>
<th>COMPOUND</th>
<th>RATIO (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>METHANE</td>
<td>65</td>
</tr>
<tr>
<td>ETHANE</td>
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<tr>
<td>PROPANE</td>
<td>2</td>
</tr>
<tr>
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<td>0.4</td>
</tr>
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<tr>
<td>CARBON DIOXIDE</td>
<td>25</td>
</tr>
<tr>
<td>NITROGEN</td>
<td>2</td>
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</tbody>
</table>
FIG. 12

Diagram showing the relationship between temperature (°C) and pressure (atm) for different atmospheric pressures: 1 atm, 2 atm, 5 atm, 10 atm, and 20 atm.
FIG. 13

MELTING POINT OF n-PENTANE

MELTING POINT OF HYDROGEN SULFIDE

PRESSURE (atm)

UPPER LIMIT

LOWER LIMIT

TEMPERATURE (°C)
METHOD OF REFINING NATURAL GAS AND
NATURAL GAS REFINING SYSTEM

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to a method of refining natural gas mined in a natural gas field or an oil field, and to a natural gas refining system.

[0003] 2. Description of the Related Art

[0004] Natural gas mined in a natural gas field or an oil field is generally cooled by liquefaction equipment and converted to liquefied natural gas (LNG). Natural gas generally contains methane as a main component of liquefied natural gas and also impurities such as hydrocarbons other than methane, carbon dioxide, sulfur compounds, and mercury. When natural gas is cooled and liquefied without removal of the impurities, the problems arise, for instance, that the impurities are solidified and liquefaction equipment (such as heat transfer equipment) is blocked, or that liquefied natural gas decreases in quality. Therefore, it is necessary to remove the impurities. Examples of a method of removing the impurities, especially carbon dioxide or hydrogen sulfide which solidify during the liquefaction process of liquefying natural gas, include a chemical absorption method or a physical adsorption method in which such impurities as carbon dioxide or hydrogen sulfide are separated in the gas phase.

[0005] For instance, JP-A-2005-515298 describes the method of separating natural gas to a solid phase and a liquid phase after adjusting a pressure and temperature of the natural gas so that methane contained in the natural gas is converted to the liquid phase and the impurities such as carbon dioxide and hydrogen sulfide to the solid phase (namely, natural gas to a suspension liquid). In the conventional technique described in JP-A-2005-515298, natural gas is expanded by a Joule Thompson valve to adjust a pressure to a range from 150 to 250 psia (a range from 1.0 MPa to 1.7 MPa) and a temperature to a range from about -100 to about -125 °C, and the expanded gas is supplied to a cryogenic tank. Further, liquefied natural gas in the sub-cool state is supplied to the cryogenic tank and the natural gas is cooled to -140 °C. With the operations described above, liquefied natural gas (suspension liquid) taken out from a lower side of the cryogenic tank is separated, for instance, with a cyclone, from a solid containing carbon dioxide, hydrogen sulfide, and the like.

SUMMARY OF THE INVENTION

[0006] In the conventional technique described in JP-A-2005-515298, a temperature and pressure of natural gas is adjusted so that methane contained in natural gas is converted to the liquid phase and impurities contained therein such as carbon dioxide and hydrogen sulfide are converted to the solid phase to realize separation between the solid phase and the liquid phase. However, some hydrocarbons other than methane contained in natural gas may remain in the liquid state and be contained in liquefied natural gas in the liquid phase state. In this case, the product quality may be deteriorated because the combustion efficiency is affected depending on a content of hydrocarbons other than methane in the liquefied natural gas. On the other hand, the hydrocarbons (such as ethane or propane) other than methane are useful materials, and therefore it has been desired to separate and recover the hydrocarbons from the liquefied natural gas.

[0007] An object of the present invention is to provide a method of refining natural gas and a natural gas refining system which can improve quality of liquefied natural gas and enable separation and recovery of the hydrocarbons other than methane.

[0008] (1) To achieve the object described above, the present invention provides a method of refining natural gas containing methane; any other hydrocarbon selected from the group consisting of ethane, ethylene, propane, propylene, n-butane, isobutane, 1-butene, n-pentane, and isopentane; carbon dioxide; and hydrogen sulfide, and the method comprises the steps of adjusting a pressure and temperature of the natural gas so that the methane is in the gas phase, the other hydrocarbon in the liquid phase, and the carbon dioxide and the hydrogen sulfide in the solid phase, respectively; separating the natural gas, of which the pressure and temperature has been adjusted, into a gas containing the methane and a suspension liquid, and separating the separated suspension liquid into a liquid containing the other hydrocarbon and a solid containing the carbon dioxide and the hydrogen sulfide.

[0009] (2) In the method described in (1) above, preferably the temperature of the natural gas is adjusted to a value less than a boiling point of ethylene but equal to or higher than a melting point of n-pentane.

[0010] (3) In the method described in (1) above, preferably the pressure of the natural gas is adjusted in a range from 1 to 10 atm.

[0011] (4) In the method described in (1) above, preferably the pressure and temperature of the natural gas is adjusted by adiabatic-expanding the natural gas with expanding means.

[0012] (5) In the method described in (1), preferably the pressure and temperature of the natural gas is adjusted by mixing liquefied natural gas in the natural gas with mixing means.

[0013] (6) In the method described in (1) above, preferably the suspension liquid is separated into the liquid containing the other hydrocarbon and the solid containing the carbon dioxide and the hydrogen sulfide with a cyclone.

[0014] (7) In the method described in (1) above, preferably in the range in which the pressure of the natural gas is 1 atm or more and the temperature of the natural gas is a value less than a melting point of the hydrogen sulfide but equal to or higher than a melting point of n-pentane, the pressure and temperature of the natural gas is adjusted so that a concentration of methane in the gas phase is 90% or more.

[0015] (8) In the method described in (7) above, preferably the temperature of the natural gas is adjusted to a value less than a boiling point of ethylene.

[0016] (9) In the method described in (7) above, preferably the pressure of the natural gas is adjusted to 10 atm or below.

[0017] (10) In the method described in (7) above, preferably the temperature of the natural gas is adjusted to a value less than a boiling point of ethylene and the pressure of the natural gas is adjusted to 10 atm or below.

[0018] (11) To achieve the object described above, the present invention provides a natural gas refining system for refining gas containing methane; any other hydrocarbon selected from the group consisting of ethane, ethylene, propane, propylene, n-butane, isobutane, 1-butene, n-pentane, and isopentane; carbon dioxide; and hydrogen sulfide, and the system comprises pressure/temperature adjusting means for adjusting a pressure and temperature of the natural gas so
that the methane is in the gas phase, the other hydrocarbon in the liquid phase, and the carbon dioxide and the hydrogen sulfide in the solid phase, respectively; gas separating means for separating the natural gas, of which the pressure and temperature adjusted by the pressure/temperature adjusting means, into a gas containing methane and a suspension liquid; and solid/liquid separating means for separating the suspension liquid separated by the gas separating means into a liquid containing the other hydrocarbon and a solid containing the carbon dioxide and the hydrogen sulfide.

[0019] (12) In the system described in (11) above, preferably the pressure/temperature adjusting means adjusts the temperature of the natural gas to a value less than a boiling point of ethylene but equal to or higher than a melting point of pentane.

[0020] (13) In the system described in (11) above, preferably the pressure/temperature adjusting means adjusts the pressure of the natural gas in a range from 1 to 10 atm.

[0021] (14) In the system described in (11) above, preferably the pressure/temperature adjusting means has expanding means for adiabatic-expanding the natural gas.

[0022] (15) In the system described in (11) above, preferably the pressure/temperature adjusting means has mixing means for mixing liquefied natural gas in the natural gas.

[0023] (16) In the system described in (11) above, preferably the solid/liquid separating means is a cyclone.

[0024] (17) In the system described in (11) above, preferably in the range in which the pressure is 1 atm or more and the temperature of the natural gas is a value less than a melting point of the hydrogen sulfide but equal to or higher than a melting point of n-pentane, the pressure/temperature adjusting means adjusts the pressure and temperature of the natural gas so that a concentration of methane in the gas phase is 90% or more.

[0025] (18) In the system described in (17) above, preferably the pressure/temperature adjusting means adjusts the temperature of the natural gas to a value less than a boiling point of ethylene.

[0026] (19) In the system described in (17) above, preferably the pressure/temperature adjusting means adjusts the pressure of the natural gas to 10 atm or below.

[0027] (20) In the system described in (17) above, preferably the pressure/temperature adjusting means adjusts the temperature of the natural gas to a value less than a boiling point of ethylene and the pressure of the natural gas to 10 atm or below.

[0028] With the present invention, product quality of liquefied natural gas can be improved, and in addition hydrocarbons other than methane can be separated and recovered.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029] FIG. 1 is a schematic diagram illustrating the configuration of a natural gas refining system according to an embodiment of the present invention.

[0030] FIG. 2 is a view showing boiling points and melting points of components contained in natural gas at 1 atm.

[0031] FIG. 3 is a schematic diagram illustrating the configuration of a first modification of the natural gas refining system according to the present invention.

[0032] FIG. 4 is a schematic diagram illustrating the configuration of a second modification of the natural gas refining system according to the present invention.

[0033] FIG. 5 is a schematic diagram illustrating the configuration of a third modification of the natural gas refining system according to the present invention.

[0034] FIG. 6 is a view showing the composition of natural gas when the natural gas contains n-pentane.

[0035] FIG. 7 is a view showing methane concentration in refined gas obtained from the natural gas containing n-pentane.

[0036] FIG. 8 is a view showing ranges of a pressure and temperature required when a methane concentration of refined gas obtained from the natural gas containing n-pentane is 90% or more.

[0037] FIG. 9 is a view showing ranges of a pressure and temperature required when a methane concentration of refined gas obtained from natural gas containing ethylene is 90% or more.

[0038] FIG. 10 is a view showing ranges of a pressure and temperature required when a methane concentration of refined gas obtained from natural gas containing ethylene is 90% or more in the case where the natural gas refining system according to the present invention is configured with low pressure devices.

[0039] FIG. 11 is a view showing the composition of natural gas when the natural gas contains various hydrocarbons.

[0040] FIG. 12 is a view showing methane concentrations in refined gas obtained from natural gas containing various hydrocarbons.

[0041] FIG. 13 is a view showing ranges of a pressure and temperature required when a methane concentration of refined gas obtained from natural gas containing various hydrocarbons is 90% or more.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0042] An embodiment of the present invention is described below with reference to the drawings.

[0043] FIG. 1 is a schematic diagram illustrating a natural gas refining system according to an embodiment of the present invention.

[0044] In FIG. 1, the natural gas refining system is installed in a plant for producing liquefied natural gas (LNG) from natural gas mixed in a natural gas field or in an oil field. The natural gas refining system comprises a separation tank 1 (a gas/solid separating unit), a nozzle 2 (a pressure/temperature adjusting unit) for injecting natural gas into the separation tank 1, a natural gas feed line 3, a liquefied natural gas feed line 4, a gas takeoff line 5, a suspension liquid takeoff line 6, and a cyclone 7 (a solid/liquid separating unit). The natural gas feed line 3 supplies natural gas (more specifically, natural gas just mixed in a natural gas field or in an oil field, or natural gas pressurized to about 60 atm (6 MPa)) to the nozzle 2. The liquefied natural gas feed line 4 supplies a portion of the liquefied natural gas produced in the plant to the nozzle 2. The gas takeoff line 5 is connected to an upper portion of the separation tank 1. The suspension liquid takeoff line 6 is connected to a lower portion of the separation tank 1. The cyclone 7 is connected to the suspension liquid takeoff line 6.

[0045] The nozzle 2 is a mixing and expanding type nozzle (a mixing unit and an expanding unit), although the details thereof are not shown in the figure. The nozzle 2 mixes liquefied natural gas (LNG) supplied through the liquefied natural gas feed line 4 in natural gas supplied from the natural gas feed line 3, and diffusively injects the resulting mixture into the separation tank 1 to subject the mixture to adiabatic
expansion so that a pressure and a temperature of the natural gas are decreased. With this operation, the pressure of the natural gas is adjusted to a range from 1 to 10 atm (a range from 0.1 to 1 MPa) (preferably to a range from 1 to 2 atm (a range from 0.1 to 0.2 MPa)). The temperature of the natural gas is adjusted to a value less than a boiling point of ethylene but equal to or higher than a melting point of n-pentane. FIG. 2 is a view showing boiling points and melting points of components contained in natural gas (for instance, methane, ethane, ethylene, propane, propylene, n-butane, isobutane, 1-butene, n-pentane, isopentane, carbon dioxide, and hydrogen sulfide) at 1 atm (0.1 MPa). As clearly understood from FIG. 2, when temperature of natural gas is adjusted to a value less than a boiling point of ethylene but equal to or higher than a melting point of n-pentane (for instance, to a range from a value less than –104°C to a value equal to or equal to or higher than –129.7°C at 1 atm (0.1 MPa)), methane contained in the natural gas is converted to the gas phase, other hydrocarbon (more specifically, any of ethane, ethylene, propane, propylene, n-butane, isobutane, 1-butene, n-pentane, and isopentane) to the liquid phase, and carbon dioxide and hydrogen sulfide to the solid phase.

In the separation tank 1, because of a difference in the specific gravity, a gas containing methane moves upward, while a suspension liquid in which a liquid containing other hydrocarbon and a solid containing carbon dioxide and hydrogen sulfide are mixed moves downward, so that the gas and the suspension liquid are separated from each other. Then, the gas separated in the separation tank 1 is supplied to liquefaction equipment (more specifically, heat transfer equipment for cooling the gas containing methane or a compressor for which the gas containing methane is used as a cooling medium) is supplied via the gas takeoff line 5. Furthermore, the suspension liquid separated in the separation tank 1 is supplied via the suspension liquid takeoff line 6 to the cyclone 7.

The cyclone 7 is a known unit available for the purpose as described above, and separates the suspension liquid into a liquid containing other hydrocarbon and a solid containing carbon dioxide and hydrogen sulfide. The separated liquid is recovered via a liquid takeoff line 8, while the separated solid is recovered via a solid takeoff line 9. The other hydrocarbon recovered as described above is further separated to respective components by, for instance, distillation equipment (not shown) and used for other purposes.

Operations of and effects by the natural gas refining system having the configuration as described above according to this embodiment will be described below.

In this embodiment, liquefied natural gas is mixed in natural gas with the mixing and expanding type nozzle 2, and the resulting mixture is injected into the separation tank 1 and subjected to adiabatic expansion there to decrease the pressure and the temperature of the natural gas. In this step, the pressure of the natural gas is adjusted to a range from 1 to 10 atm (a range from 0.1 to 1 MPa) and also the temperature of the natural gas is adjusted to a value less than a boiling point of ethylene but equal to or higher than a melting point of n-pentane. Therefore methane contained in the natural gas is converted to the gas phase, other hydrocarbon (more specifically, any of ethane, ethylene, propane, propylene, n-butane, isobutane, 1-butene, n-pentane, and isopentane) to the liquid phase, and carbon dioxide and hydrogen sulfide to the solid phase. Then, the natural gas is separated to the gas containing methane and the suspension liquid, and the separated gas phase is supplied to the liquefaction equipment to produce liquefied natural gas. With the process, not only carbon dioxide and hydrogen sulfide contained in the natural gas, but also the other hydrocarbon can be separated to produce liquefied natural gas with improved product quality. On the other hand, the suspension liquid separated in the separation tank 1 is continuously processed with the cyclone 7 to be separated and recovered as a liquid containing the other hydrocarbon and a solid containing carbon dioxide and hydrogen sulfide. In this way, hydrocarbons other than methane can be separated and recovered, and hydrocarbons other than the recovered methane can be utilized for various purposes.

Furthermore, in this embodiment, the natural gas is adjusted with the nozzle 2 to the pressure range from 1 to 10 atm (a range from 0.1 to 1 MPa), and therefore as compared to a case where the pressure is adjusted to a value higher than 10 atm (1 MPa), the conditions for pressure resistance can be mitigated. Accordingly, it enables cost reduction in manufacturing the refining system.

Although not specifically described in the embodiment above, a pressure and temperature of natural gas may be adjusted by controlling a flow rate of liquefied natural gas to be supplied to the nozzle 2. In other words, although not shown, the natural gas refining system may include a pressure sensor for detecting a pressure in the separation tank 1 and a temperature sensor for detecting a temperature in the separation tank 1. Further, the natural gas refining system may include a flow control valve provided on the liquefied natural gas feed line 4 for controlling a flow rate of liquefied natural gas, and a control unit for controlling the flow control valve so that values detected by the pressure sensor and the temperature sensor are set to target values. Also in this configuration, the effects as described above are provided.

The embodiment has been described with reference to a case where the mixing and expanding type nozzle 2 is employed as an expanding unit for adiabatic-expanding the natural gas and also as a mixing unit for mixing liquefied natural gas in natural gas, but the present invention is not limited to the configuration. Specifically, for instance, a mixing valve as a mixing unit and an expansion valve as an expanding unit may be provided in place of the nozzle 2. For instance, in the case where the target temperature conditions for natural gas are achieved only by means of adiabatic expansion, the configuration is allowable in which the mixing unit is not provided and only the expanding unit is provided. Also in this configuration, the effects as described above are provided.

The embodiment described above is based on the configuration in which the cyclone 7 continuously processes the suspension liquid separated in the separation tank 1, but the present invention is not limited to this configuration. Specifically, for instance, as shown in FIG. 3, also the configuration is allowable in which a switching valve 10 is provided on the suspension takeoff line 6 in such a manner that it is opened or closed according to the necessity. Also in a first modification, the same effects as those described above can be provided. In this modification, the cyclone 7 can efficiently be operated according to a required processing rate of natural gas and contents of components other than methane.

In the embodiment above, an internal structure of the separation tank 1 is not specifically described, but, for instance, as shown in FIG. 4, a plurality of inclined trays (four shelves in FIG. 4) may be provided inside the separation tank 1. Also in a second modification, the same effects as those in
the embodiment described above can be provided. Furthermore, in this modification, a partial pressure of methane in the gas decreases in the lower trays (lower ones in FIG. 4) while methane in the liquid phase is likely to be converted to the gas phase. As a result, improvement in the recovery rate of methane is achieved. Furthermore, a temperature control unit such as a heater may be provided so that a temperature in the lower tray 11 is higher than that in the upper tray 11. With the configuration, a vapor pressure of methane becomes larger in the lower trays, and therefore methane in the liquid phase is likely to shift to the gas phase. As a result, improvement in the recovery rate of methane is achieved.

[0055] The above embodiment has been described with reference to the case where the cyclone 7 is provided as a solid/liquid separating unit for separating the suspension liquid separated in the separation tank 1 to a solid phase and a liquid phase, but the present invention is not limited to this configuration. Specifically, for instance, filtration equipment or distillation equipment may be provided in place of the cyclone 7. Furthermore, description of the embodiment above has been made with reference to the case where the separation tank 1 and the cyclone 7 are provided independently, but the present invention is not limited to this configuration. Specifically, as shown in FIG. 5, the cyclone 7 is provided at a portion below the separation tank 1 in such a manner that the separation tank 1 and the cyclone 7 are integrally formed. Also in the third modification, the same effects as those in the embodiment above can be obtained.

[0056] In the embodiment described above, a pressure and temperature of natural gas in the separation tank 1 is adjusted so that methane contained in natural gas is converted to the gas phase, other hydrocarbons to the liquid phase, and the carbon dioxide and hydrogen sulfide to the solid phase, respectively. This does not always mean that all of methane contained in the natural gas, all of the other hydrocarbons, and carbon dioxide and hydrogen sulfide are converted to the gas phase, liquid phase, and solid phase, respectively. Specifically, a concentration of methane in the refined gas depends on a composition, a pressure, and a temperature of natural gas in the separation tank 1.

[0057] Description is provided below for a method of setting a pressure and temperature in the separation tank 1 for making higher a concentration of methane in refined gas with reference to the simulated natural gas as shown in FIG. 6. The simulated natural gas comprises three components of methane, carbon dioxide, and n-pentane having the highest melting point among the hydrocarbons other than methane shown in FIG. 2.

[0058] FIG. 7 shows concentrations of methane in refined gas when the simulated natural gas is separated at various pressures and temperatures. A concentration of methane in liquefied natural gas is required to be higher than a value slightly lower than 90% indicating a percentage of methane contained in town gas when the refined gas is used as town gas. Therefore, it is desirable that the methane concentration in the refined gas be 90% or more. As understood from the figure, when the pressure is high, it is possible to raise to 90% the methane concentration in refined gas at a higher temperature.

[0059] FIG. 8 shows a pressure and a temperature when refined gas obtained from the simulated natural gas has a concentration of methane of 90% or more (This figure is prepared from FIG. 7). In this figure, ○ represents a pressure at which the methane concentration in the refined gas is maximized at each temperature, △ (overlaying on ○ in this figure) represents an upper limit pressure when the methane concentration in the refined gas is 90% or more at each temperature, and ▲ represents a lower limit pressure at which the methane concentration in the refined gas is 90% or more at each temperature. This means that when the pressure and temperature is in the area from the upper limit to the lower limit, most of methane is converted to a gas phase.

[0060] Since it is not necessary to provide a depressurizing unit such as a vacuum pump in the separation tank 1, the pressure range is preferably 1 atm (0.1 MPa) or more. Furthermore, because the hydrocarbons other than methane are converted to the liquid phase and carbon dioxide and hydrogen sulfide to the solid phase, the temperature range is required to be less than a boiling point of hydrogen sulfide and at the same time equal to or higher than a melting point of n-pentane. Specifically, when the pressure and temperature is in the hatched area in FIG. 8, the methane concentration in the refined gas can be made higher so that methane contained in the natural gas is converted to the gas phase, other hydrocarbons to the liquid phase, and carbon dioxide and hydrogen sulfide to the solid phase, respectively.

[0061] Next, description is provided for ranges of a pressure and temperature when natural gas contains ethylene with reference to FIG. 9. Ethylene is a compound having the lowest boiling point among the components other than methane shown in FIG. 2. Because most of ethylene is to be converted to the liquid phase, the temperature range is required to be less than a boiling point of ethylene. Specifically, when the pressure and temperature is in the hatched area in the figure, the methane concentration in the refined gas can be made higher so that methane contained in natural gas is converted to the gas phase, other hydrocarbons to the liquid phase, and carbon dioxide and hydrogen sulfide to the solid phase, respectively.

[0062] As described above, when the pressure is set to 10 atm (1 MPa) or below, the conditions for pressure resistance can be mitigated as compared to the case where the pressure is 10 atm (1 MPa) or more. Accordingly, it is possible to reduce manufacturing cost for the refining system. When the pressure and temperature is in the hatched area in FIG. 10, it is possible to configure a natural gas refining system with low-pressure devices and to make higher a methane concentration in refined gas so that methane contained in the natural gas is converted to the gas phase, other hydrocarbons to the liquid phase, and carbon dioxide and hydrogen sulfide to the solid phase, respectively.

[0063] A method of setting a pressure and temperature for raising a methane concentration in refined gas when the natural gas contains various hydrocarbons is described below with reference to FIGS. 11 to 13.

[0064] FIG. 11 is a view showing the composition of natural gas when the natural gas contains various hydrocarbons. The methane concentration in refined gas obtained from natural gas shown in FIG. 11 is determined as shown in FIG. 12. When a pressure and temperature required for the methane concentration of 90% or more in the refined gas shown in FIG. 12 is determined, FIG. 13 can be prepared.

[0065] Differences between FIG. 13 and FIG. 8 are described below. When the natural gas contains various hydrocarbons, a pressure at which the methane concentration in refined gas at each temperature is maximized (represented by ○ in the figure) is separated from an upper limit pressure at which the methane concentration in the refined gas is 90%
or more at each temperature (represented by A in the figure). However, the upper limit changes little.

[0066] On the other hand, a lower limit pressure at which the methane concentration in refined gas at each temperature is 90% (represented by V in the figure) becomes higher due to effects by hydrocarbons other than methane and n-pentane. Therefore, ranges of a pressure and a temperature (in the hatched area in the figure) at which the methane concentration in the refined gas can be made higher so that the methane contained in the natural gas is converted to the gas phase, other hydrocarbons to the liquid phase, and carbon dioxide and hydrogen sulfide to the solid phase respectively are narrower as compared to those shown in FIG. 8. In other words, the ranges of a pressure and a temperature are included in the ranges of a pressure and a temperature shown in FIG. 8.

What is claimed is:

1. A method of refining natural gas containing methane; any other hydrocarbon selected from the group consisting of ethane, ethylene, propane, propylene, n-butane, isobutane, 1-butene, n-pentane, and isopentane; carbon dioxide; and hydrogen sulfide, the method comprising the steps of:
   adjusting a pressure and temperature of the natural gas so that the methane is in the gas phase, the other hydrocarbon in the liquid phase, and the carbon dioxide and the hydrogen sulfide in the solid phase, respectively;
   separating the natural gas, of which the pressure and temperature has been adjusted, into a gas containing the methane and a suspension liquid; and
   separating the separated suspension liquid into a liquid containing the other hydrocarbon and a solid containing the carbon dioxide and the hydrogen sulfide.

2. The method of refining natural gas according to claim 1, wherein the temperature of the natural gas is adjusted to a value less than a boiling point of ethylene but equal to or higher than a melting point of n-pentane.

3. The method of refining natural gas according to claim 1, wherein the pressure of the natural gas is adjusted in a range from 1 to 10 atm.

4. The method of refining natural gas according to claim 1, wherein the pressure and temperature of the natural gas is adjusted by adiabatic-expanding the natural gas with expanding means.

5. The method of refining natural gas according to claim 1, wherein the temperature and pressure of the natural gas is adjusted by mixing liquefied natural gas in the natural gas with mixing means.

6. The method of refining natural gas according to claim 1, wherein the suspension liquid is separated into the liquid containing the other hydrocarbon and the solid containing the carbon dioxide and the hydrogen sulfide with a cyclone.

7. The method of refining natural gas according to claim 1, wherein in the range in which the pressure of the natural gas is 1 atm or more and the temperature of the natural gas is a value less than a melting point of the hydrogen sulfide but equal to or higher than a melting point of n-pentane, the pressure and temperature of the natural gas is adjusted so that a concentration of methane in the gas phase is 90% or more.

8. The method of refining natural gas according to claim 7, wherein the temperature of the natural gas is adjusted to a value less than a boiling point of ethylene.

9. The method of refining natural gas according to claim 7, wherein the pressure of the natural gas is adjusted to 10 atm or below.

10. The method of refining natural gas according to claim 7, wherein the temperature of the natural gas is adjusted to a value less than a boiling point of ethylene and the pressure of the natural gas is adjusted to 10 atm or below.

11. A natural gas refining system for refining gas containing methane; any other hydrocarbon selected from the group consisting of ethane, ethylene, propane, propylene, n-butane, isobutane, 1-butene, n-pentane, and isopentane; carbon dioxide; and a hydrogen sulfide, the refining system comprising:
   pressure/temperature adjusting means for adjusting a pressure and temperature of the natural gas so that the methane is in the gas phase, the other hydrocarbon in the liquid phase, and the carbon dioxide and the hydrogen sulfide in the solid phase, respectively;
   gas separating means for separating the natural gas, of which the pressure and temperature adjusted by the pressure/temperature adjusting means, into a gas containing the methane and a suspension liquid; and
   solid/liquid separating means for separating the suspension liquid separated by the gas separating means into a liquid containing the other hydrocarbon and a solid containing the carbon dioxide and the hydrogen sulfide.

12. The natural gas refining system according to claim 11, wherein the pressure/temperature adjusting means adjusts the temperature of the natural gas to a value less than a boiling point of ethylene and also adjusts the temperature of the natural gas to 10 atm or below.

13. The natural gas refining system according to claim 11, wherein the pressure/temperature adjusting means adjusts the pressure of the natural gas in a range from 1 to 10 atm.

14. The natural gas refining system according to claim 11, wherein the pressure/temperature adjusting means has expanding means for adiabatic-expanding the natural gas.

15. The natural gas refining system according to claim 11, wherein the pressure/temperature adjusting means has mixing means for mixing liquefied natural gas in the natural gas.

16. The natural gas refining system according to claim 11, wherein the solid/liquid separating means is a cyclone.

17. The natural gas refining system according to claim 11, wherein in the range in which the pressure of the natural gas is 1 atm or more and the temperature of the natural gas is a value less than a melting point of the hydrogen sulfide but equal to or higher than a melting point of n-pentane, the pressure/temperature adjusting means adjusts the pressure and temperature of the natural gas so that a concentration of methane in the gas phase is 90% or more.

18. The natural gas refining system according to claim 17, wherein the pressure/temperature adjusting means adjusts the temperature of the natural gas to a value less than a boiling point of ethylene.

19. The natural gas refining system according to claim 17, wherein the pressure/temperature adjusting means adjusts the pressure of the natural gas to 10 atm or below.

20. The natural gas refining system according to claim 17, wherein the pressure/temperature adjusting means adjusts the temperature of the natural gas to a value less than a boiling point of ethylene and also adjusts the pressure of the natural gas to 10 atm or below.