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(54) **TREATING LIQUEFIED NATURAL GAS**

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(57) **ABSTRACT**

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Method of treating liquefied natural gas (1) to obtain a liquid stream (21) having a reduced content of components having low boiling points comprising expanding (3) the liquefied gas to expand to obtain expanded two-phase fluid; introducing the two-phase fluid into a column (10) below a gas-liquid contacting section (14); withdrawing from the bottom (16) a liquid-stream (17) having a reduced content of components having low boiling points; withdrawing from the top (23) of the column (10) a gaseous stream (25) enriched in components having low boiling points; heating the gaseous stream in a heat exchanger (27); compressing (30) the stream to fuel gas pressure to obtain fuel gas (33); separating a recycle stream (34a) from the fuel gas; at least partly condensing (27) the recycle stream to obtain a reflux stream (34b); and introducing the reflux stream (34b) into the column (10) above the contacting section (14).

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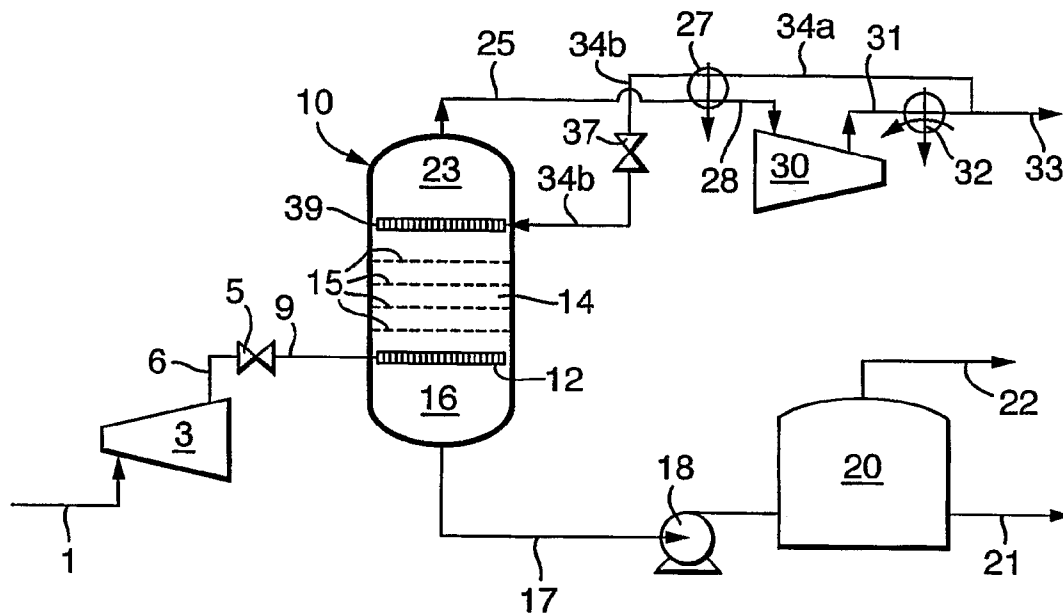




Fig.3.

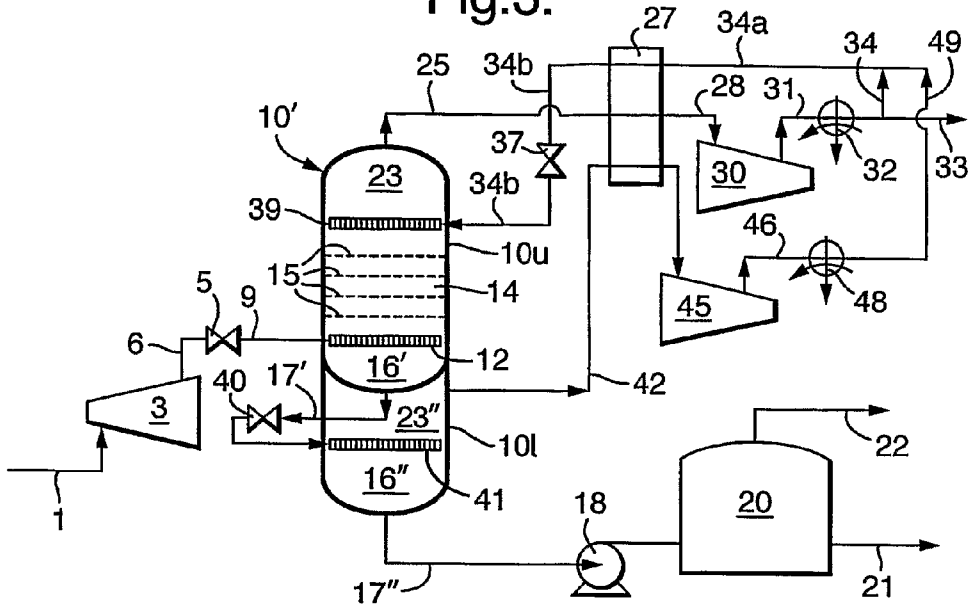
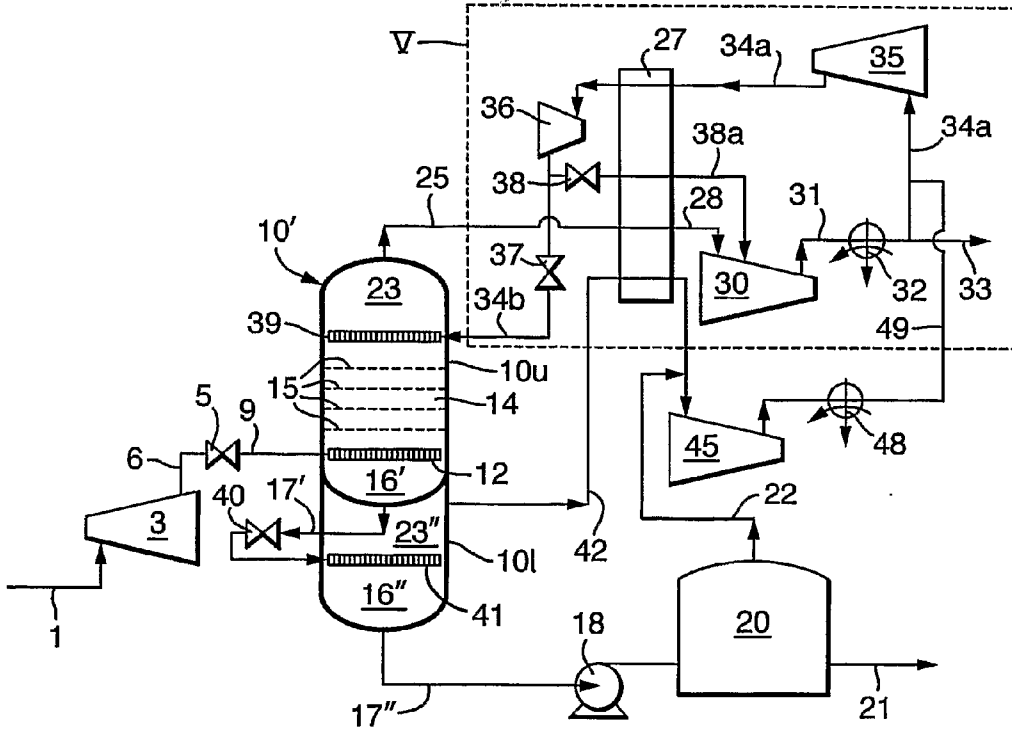


Fig.4.





### TREATING LIQUEFIED NATURAL GAS

[0001] The present invention relates to treating liquefied natural gas, and in particular treating liquefied natural gas that contains components having boiling-points lower than methane. An example of such a component is nitrogen. In the specification and in the claims the expressions 'low boiling point components' and 'components having low boiling points' will be used to refer to components having boiling points lower than methane. The treatment is directed to removing low boiling point components from the liquefied natural gas in order to obtain a liquefied natural gas having a reduced content of components having low boiling points. The improved method can be applied in two ways: (1) to treat the same amount of liquefied natural gas as in a conventional method, or (2) to treat a larger amount of liquefied natural gas as in a conventional method. When applied in the first way, the content of low boiling point components in the liquefied gas treated with the method of the present invention is lower than that in liquefied gas treated with a conventional method. When applied in the second way, the content of low boiling point components is maintained and the amount of liquefied gas is increased.

[0002] U.S. Pat. No. 6,199,403 discloses a method to remove a high-volatility component such as nitrogen from a feed stream rich in methane. According to U.S. Pat. No. 6,199,403 the expanded liquefied natural gas stream enters a separation column at an intermediate level, i.e. not below a gas-liquid contacting section.

[0003] U.S. Pat. No. 5,421,165 relates to a process for denitrogenation of a feedstock of a liquefied mixture of hydrocarbons. To this end U.S. Pat. No. 5,421,165 suggests a relatively complicated process using a denitrogenation column comprising a plurality of theoretical fractionation stages.

[0004] Another relatively complicated process has been described in International patent application publication No. WO 02/50483. WO 02/50483 discloses several methods of removing components having low boiling points from liquefied natural gas. According to WO 02/50483 a liquid product stream having a reduced content of components having low boiling points is obtained.

[0005] A problem of the above processes described in WO 02/50483 is that the liquid product stream contains an undesirable high content of components having low boiling points.

[0006] It is an object of the present invention to minimize the above problem.

[0007] It is a further object of the present invention to provide an alternative process.

[0008] It is an even further object of the present invention to provide a simplified process to reduce the amount of components having low boiling points in a liquefied natural gas stream.

[0009] One or more of the above or other objects are achieved according to the present invention by providing a method of treating liquefied natural gas supplied at liquefaction pressure containing components having low boiling points to obtain a liquid product stream having a reduced content of components having low boiling points, which method comprises the steps of:

[0010] (a) allowing the liquefied gas to expand to separation pressure to obtain an expanded two-phase fluid;

[0011] (b) introducing the expanded two-phase fluid into a column below a gas-liquid contacting section arranged in the column;

[0012] (c) collecting in the bottom of the column liquid from the two-phase fluid and withdrawing from the bottom of the column a liquid stream having a reduced content of components having low boiling points; introducing the liquid stream into a flash vessel at a low pressure; removing a second gaseous stream from the top of the flash vessel; and removing from the bottom of the flash vessel a liquid stream to obtain the liquid product stream;

[0013] (d) allowing vapor from the two-phase fluid to flow through the contacting section;

[0014] (e) withdrawing from the top of the column a gaseous stream that is enriched in components having low boiling points;

[0015] (f) heating the gaseous stream obtained in step (e) in a heat exchanger to obtain a heated gaseous stream;

[0016] (g) compressing the heated gaseous stream obtained in step (f) to fuel gas pressure to obtain fuel gas;

[0017] (h) separating a recycle stream from the fuel gas obtained in step (g);

[0018] (i) at least partly condensing the recycle stream obtained in step (h) to obtain a reflux stream; and

[0019] (j) introducing the reflux stream obtained in step (i) at separation pressure into the column above the contacting section.

[0020] Applicants have found that the liquid product stream obtained according to the present invention contains a smaller content of components having low boiling points than one would expect.

[0021] An important advantage of the method according to the present invention is that it can be suitably used for large liquefaction plants.

[0022] The present invention will now be illustrated by way of example in more detail with reference to the non-limiting accompanying drawings, wherein:

[0023] FIG. 1 shows schematically a process flow scheme illustrating a part of an embodiment of the method of the present invention (not including a flash vessel as required according to the present invention);

[0024] FIG. 2 shows schematically an alternative of the process of FIG. 1;

[0025] FIG. 3 shows schematically a process flow scheme of a fully elaborated embodiment of the method of the present invention, including a flash vessel;

[0026] FIG. 4 shows schematically an alternative of the process of FIG. 3;

[0027] FIG. 5 shows schematically and not to scale an alternative to part V of the process flow scheme of FIG. 4; and

[0028] FIG. 6 shows the process according to FIG. 4 having two contacting zones.

[0029] Reference is made to FIG. 1. Liquefied natural gas containing components having low boiling points is supplied at liquefaction pressure through conduit 1 to an expansion device in the form of expansion engine 3 and Joule-Thompson valve 5 in the discharge conduit 6 of expansion engine 3. In the expansion device, the liquefied gas is allowed to expand to separation pressure, and an expanded two-phase fluid is obtained. The liquefaction pressure is suitably in the range of from 3 to 8.5 MPa and the separation pressure is suitably in the range of from 0.1 to 0.5 MPa.

[0030] The expanded two-phase fluid is passed through conduit 9 to a column 10. The expanded two-phase fluid is introduced into the column 10 at separation pressure via a suitable inlet device, such as vane inlet device 12. The vane inlet device, also known as schoepentoeter, allows efficient separation of gas and liquid.

[0031] The column 10 is provided with a gas-liquid contacting section 14. The contacting section 14 may comprise any suitable means for contacting a gas and a liquid, such as trays and packings. Preferably, the contacting section 14 consists of between two and eight horizontal contacting trays 15. The expanded two-phase fluid is introduced into the column 10 below the gas-liquid contacting section 14. The person skilled in the art will readily understand that the column may comprise two or more contacting sections 14.

[0032] In the bottom 16 of the column 10 liquid from the two-phase fluid is collected, and a liquid stream having a reduced content of components having low boiling points is removed from the bottom 16 through conduit 17 and pumped by pump 18 to a storage tank 20. From the storage tank 20 a liquid product stream is removed through conduit 21 and a gaseous stream through conduit 22. The gaseous stream is also known as boil-off gas.

[0033] Vapor from the two-phase fluid to flow through the contacting section 14. From the top 23 of the column 10 a gaseous stream that is enriched in components having low boiling points is removed through conduit 25. The gaseous stream is heated in a heat exchanger 27 to obtain a heated gaseous stream that is passed through conduit 28 to a compressor 30. In compressor 30 the heated gaseous stream is compressed to fuel gas pressure to obtain fuel gas. The fuel gas is removed through conduit 31 and cooled in heat exchanger 32 to remove the heat of compression. The fuel gas is passed away through conduit 33. The fuel gas pressure is in the range of from 1 to 3.5 MPa.

[0034] A recycle stream from the fuel gas and supplied to the heat exchanger 27 through conduit 34a. In the heat exchanger 27 the recycle stream is at least partly condensed to obtain a reflux stream, which is passed to the column 10 through the conduit 34b provided with Joule-Thompson valve 37. The reflux stream is introduced at separation pressure into the column 10 via inlet device, such as vane inlet device 39 above the contacting section 14.

[0035] Table 1 summarizes the result of a hypothetical example, wherein the method of FIG. 1 is compared to a base case. In the base case the recycle stream and the feed are introduced into the column at the same level, so that the liquid phases of the two streams are mixed before introduction thereof in the column and the column has no contacting

section. It was found that the liquid stream withdrawn through conduit 17 for the base case contains more nitrogen than the same stream for the present invention.

TABLE 1

	Embodiment of FIG. 1	Base case
Number of trays in contacting section	3	—
Flow rate feed through conduit 9	190.86 kg/s	190.86 kg/s
Temperature of feed introduced through inlet device 12	-145° C.	-145° C.
Nitrogen content in feed	3.05 mol %	3.05 mol %
Recycle flow rate	26 kg/s	26 kg/s
Temperature of recycle introduced through inlet device 39	-165.6° C.	-165.2° C.
Nitrogen content of recycle stream	Vapour phase contains 33 mol % Liquid phase contains 1.7 mol %	Total recycle stream contains 22 mol %
Flow rate of product in conduit 21	169.25 kg/s	169.19 kg/s
Nitrogen content of product in conduit 21	0.65 mol %	0.82 mol %
Flow rate of fuel gas in conduit 33	20.51 kg/s	20.59 kg/s
Nitrogen content of fuel gas	24 mol %	22 mol %
Power required for compressor 30	30.8 MW	31.2 MW

[0036] Table 1 shows that a lower nitrogen content in the product stream is obtained with the method of the present invention.

[0037] In an alternative embodiment the recycle stream separated from the fuel gas is additionally compressed in an auxiliary compressor to an elevated pressure before it is at least partly condensed in heat exchanger 27. The high-pressure recycle stream can be used in several ways, which will be discussed with reference to FIG. 2. The parts that were already discussed with reference to FIG. 1 have got the same reference numerals.

[0038] The auxiliary compressor included in conduit 34a is referred to with reference numeral 35. The auxiliary compressor 35 can be provided with a cooler (not shown) to remove the heat of compression for the compressed recycle stream. The compressed recycle stream is at least partly condensed by cooling it in heat exchanger 27. Part of the cold that is needed is provided by the gaseous stream that is enriched in components having low boiling points that is passed through conduit 25. The remainder is provided by the recycle stream. Cold from the recycle stream can be obtained by expanding a part of the recycle stream to an intermediate pressure in Joule-Thompson valve 38, using the expanded fluid to cool the recycle stream in conduit 34a and supplying the expanded fluid through conduit 38a to the compressor 30. The intermediate pressure to which the part

of the recycle stream is expanded is in the range of from the suction pressure to the discharge pressure of the compressor **30** (ends of the range included). The stage at which the expanded recycle stream enters the compressor **30** is so selected that the pressure of the expanded recycle stream matches the pressure of the fluid in the compressor **30** in that stage.

[0039] The remainder of the recycle stream is expanded by the Joule-Thompson valve **37** and introduced as reflux in the column **10** as discussed with reference to FIG. 1.

[0040] An advantage of the embodiment discussed with reference to FIG. 2 is that the recycle stream is expanded from a larger pressure and thus cooled to a lower temperature. This allows a warmer feed stream, for example a feed stream at  $-142^{\circ}\text{C}$ ., compared to a feed stream temperature of  $-145^{\circ}\text{C}$ . (in the above example). Thus the temperature of the liquefied gas from the main cryogenic heat exchanger can be higher and therefore, for the same amount of energy, more gas can be liquefied.

[0041] The elevated pressure of the fluid discharged from the auxiliary compressor **35** is so selected that the costs of the power required to drive the auxiliary compressor **35** are less than the value of the increased amount of gas that is liquefied.

[0042] In the above we discussed an embodiment in which the expansion is done in the expansion valves **37** and **38**. However, it will be understood that the expansion of the recycle stream can be done in two stages, at first in an expansion device, such as expander **36** and subsequently in the Joule-Thompson valves **37** and **38**.

[0043] Instead of supplying the expanded fluid through conduit **38a** to the compressor **30**, the expanded fluid can be supplied to an inlet (not shown) of the compressor **35**.

[0044] In the embodiments discussed with reference to FIGS. 1 and 2, the liquid from the two-phase fluid is collected in the bottom **16** of the column **10**, and from the bottom **16** a liquid stream **17** is withdrawn having a reduced content of components having low boiling points to obtain the liquid product stream. In an alternative embodiment of the invention, this step comprises collecting in the bottom of the column liquid from the two-phase fluid and withdrawing from the bottom of the column a liquid stream having a reduced content of components having low boiling points; introducing the liquid stream into a flash vessel at a low pressure; removing a second gaseous stream from the top of the flash vessel; and removing from the bottom of the flash vessel a liquid stream to obtain the liquid product stream.

[0045] This embodiment according to the present invention including a flash vessel will now be discussed with reference to FIG. 3. The parts that were already discussed with reference to FIG. 1 have got the same reference numerals.

[0046] The column **10'** comprises an upper part **10u** and a lower part **10l**, wherein the upper part performs the function of the column **10** in FIG. 1 and the lower part **10l** is a flash vessel operating at a pressure that is below the pressure in the upper part **10u**. Suitably the pressure in the upper part **10u** is in the range of from 0.2 to 0.5 MPa and the pressure in the flash vessel **10l** in the range of from 0.1 to 0.2 MPa. The person skilled in the art will readily understand that the

flash vessel **10l** may be a component that is physically separated from the column **10l** (i.e. at a certain distance).

[0047] During normal operation, liquid from the two-phase fluid supplied through conduit **9** is collected in the bottom **16'** of the upper part **10u** of the column **10'**. From that bottom **16'** is withdrawn a liquid stream having a reduced content of components having low boiling points through conduit **17'**. This stream is then introduced into the flash vessel **10l** at a low pressure. The pressure reduction is achieved by means of Joule-Thompson valve **40** in conduit **17'**. Consequently a two-phase mixture is formed and that is introduced via inlet device **41** into the flash vessel **10l**.

[0048] Through conduit **17''** a liquid stream having a reduced content of components having low boiling points is removed, which is passed to the storage tank **20**.

[0049] From the top **23''** of the flash vessel **10l** a second gaseous stream is removed.

[0050] Suitably the second gaseous stream is passed through conduit **42** to heat exchanger **27**, in which the second gaseous stream is heated by heat exchange with the recycle stream supplied through conduit **34a**. The heated stream is compressed in compressor **45**, the heat of compression is removed in heat exchanger **48** and passed through conduit **49** to add the compressed second gaseous stream to the recycle stream in conduit **34a**.

[0051] It will be understood that compressors **45** and **30** can be combined into one compressor (not shown). In that case, conduit **42** is connected to the suction end of that compressor, conduit **28** to an intermediate inlet and conduit **32** is connected to the discharge end of that compressor.

[0052] An advantage of this method is that it can be used for large liquefaction plants.

[0053] As with the embodiment discussed with reference to FIG. 1, the embodiment discussed with reference to FIG. 3 can as well be provided with an auxiliary compressor to compress the recycle stream separated from the fuel gas to an elevated pressure before it is at least partly condensed in heat exchanger **27**. The high-pressure recycle stream can be used in several ways, which will be discussed with reference to FIG. 4. The parts that were already discussed with reference to FIG. 3 have got the same reference numerals.

[0054] The auxiliary compressor included in conduit **34a** is referred to with reference numeral **35**. The auxiliary compressor **35** can be provided with a cooler (not shown) to remove the heat of compression for the compressed recycle stream. The compressed recycle stream is partially condensed by cooling it in heat exchanger **27**. Part of the cold that is needed is provided by the gaseous stream that is enriched in components having low boiling points that is passed through conduit **25**. The remainder is provided by the recycle stream. Cold from the recycle stream can be obtained by expanding a part of the recycle stream to an intermediate pressure in Joule-Thompson valve **38**, using the expanded fluid to cool the recycle stream in conduit **34a** and supplying the expanded fluid through conduit **38a** to the compressor **30**. The intermediate pressure to which the part of the recycle stream is expanded is in the range of from the suction pressure to the discharge pressure of the compressor **30** (ends of the range included). The point at which the expanded recycle stream enters the compressor **30** is so

selected that the pressure of the expanded recycle stream matches the pressure of the fluid in the compressor **30** at the inlet point.

[0055] The remainder of the recycle stream is expanded by the Joule-Thompson valve **37** and introduced as reflux in the column **10** as discussed with reference to FIG. **1**.

[0056] An advantage of this embodiment is that the recycle stream is expanded from a larger pressure and thus cooled to a lower temperature. This allows a warmer feed stream, for example a feed stream at  $-142^{\circ}\text{C}$ ., compared to a feed stream temperature of  $-145^{\circ}\text{C}$ . (in the above example). Thus the temperature of the liquefied gas from the main cryogenic heat exchanger can be higher and therefore, for the same amount of energy, more gas can be liquefied.

[0057] The elevated pressure of the fluid discharged from the auxiliary compressor **35** is so selected that the costs of the power required to drive the auxiliary compressor **35** are less than the value of the increased amount of gas that is liquefied.

[0058] In the above we discussed an embodiment in which the expansion is done in the expansion valves **37** and **38**. However, it will be understood that the expansion of the recycle stream can be done in two stages, at first in an expansion device, such as expander **36** and subsequently in the Joule-Thompson valves **37** and **38**.

[0059] FIG. **4** also shows that the boil-off gas from the storage tank **20** is provided via the conduit **22** to the suction end of the compressor **45**.

[0060] It will be understood that compressors **45** and **30** can be combined into one compressor (not shown). In that case, conduit **42** (into which conduit **22** opens) is connected to the suction end of that compressor, conduit **28** to an intermediate inlet and conduit **32** is connected to the discharge end of that compressor.

[0061] Instead of supplying the expanded fluid through conduit **38a** to the compressor **30**, the expanded fluid can be supplied to an inlet (not shown) of the compressor **35**.

[0062] An alternative of the embodiment shown in FIG. **4** is shown in FIG. **5**, wherein a part of the recycle stream that is passed through conduit **34a** is separated therefrom and passed through conduit **50** through the heat exchanger **27**. Then the cooled recycle stream is expanded to the intermediate pressure in expander **51** and used to cool the recycle stream in conduit **34a**. The expanded stream is then introduced into the compressor **30** at an intermediate stage.

[0063] Suitably, the recycle stream passed through conduit **34a** is between 10 and 90% by mass of the fuel gas that is passed through conduit **31**.

[0064] FIG. **6** shows the process according to FIG. **4** wherein the column **10u** comprises two contacting sections **14**. The skilled person will readily understand that more than two contacting sections **14** may be present.

[0065] From between the contacting sections **14**, a stream is removed via draw off device **63** and fed via line **60** to a heat exchanger **61**, wherein the stream is heat exchanged against the stream in line **1**. Subsequently the stream in line **60** is returned to the column **10u** and fed via vane inlet device **62**.

[0066] In the embodiments discussed with reference to the Figures, the contacting section **14** contains trays, however, any other contacting means such as packing can be employed as well. The length of the packed section is then preferably equivalent to between two and eight contacting trays for the section above vane inlet device **12** and between five and fifteen trays for the section below draw-off device **63**.

[0067] The method of the present invention provides a simple way of reducing the amount of components having low boiling points in a liquefied natural gas stream.

1. A method of treating liquefied natural gas supplied at liquefaction pressure containing components having low boiling points to obtain a liquid product stream having a reduced content of components having low boiling points, which method comprises the steps of:

- (a) allowing the liquefied gas to expand to separation pressure to obtain an expanded two-phase fluid;
- (b) introducing the expanded two-phase fluid into a column below a gas-liquid contacting section arranged in the column;
- (c) collecting in the bottom of the column liquid from the two-phase fluid and withdrawing from the bottom of the column a liquid stream having a reduced content of components having low boiling points; introducing the liquid stream into a flash vessel at a low pressure; removing a second gaseous stream from the top of the flash vessel; and removing from the bottom of the flash vessel a liquid stream to obtain the liquid product stream;
- (d) allowing vapor from the two-phase fluid to flow through the contacting section;
- (e) withdrawing from the top of the column a gaseous stream that is enriched in components having low boiling points;
- (f) heating the gaseous stream obtained in step (e) in a heat exchanger to obtain a heated gaseous stream;
- (g) compressing the heated gaseous stream obtained in step (f) to fuel gas pressure to obtain fuel gas;
- (h) separating a recycle stream from the fuel gas obtained in step (g);
- (i) at least partly condensing the recycle stream obtained in step (h) to obtain a reflux stream; and
- (j) introducing the reflux stream obtained in step (i) at separation pressure into the column above the contacting section.

2. The method according to claim 1, further comprising heating the second gaseous stream in the heat exchanger; compressing the second gaseous stream to fuel gas pressure; and adding the second gaseous stream to the recycle stream.

3. The method according to claim 1, wherein at least partly condensing the recycle stream comprises indirectly

heat exchanging the recycle stream with the gaseous stream(s) in the heat exchanger.

4. The method according to claim 1, wherein compressing the heated gaseous stream to fuel gas pressure to obtain fuel gas further includes removing the heat of compression.

5. The method according to claim 1, wherein the recycle stream separated from the fuel gas is compressed to an elevated pressure before it is at least partly condensed.

6. The method according to claim 2, wherein at least partly condensing the recycle stream comprises indirectly heat exchanging the recycle stream with the gaseous stream(s) in the heat exchanger.

7. The method according to claim 2, wherein compressing the heated gaseous stream to fuel gas pressure to obtain fuel gas further includes removing the heat of compression.

8. The method according to claim 3, wherein compressing the heated gaseous stream to fuel gas pressure to obtain fuel gas further includes removing the heat of compression.

9. The method according to claim 2, wherein the recycle stream separated from the fuel gas is compressed to an elevated pressure before it is at least partly condensed.

10. The method according to claim 3, wherein the recycle stream separated from the fuel gas is compressed to an elevated pressure before it is at least partly condensed.

11. The method according to claim 4, wherein the recycle stream separated from the fuel gas is compressed to an elevated pressure before it is at least partly condensed.

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