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(54) **METHOD OF COOLING A NATURAL GAS FEED STREAM AND RECOVERING A NATURAL GAS LIQUID STREAM FROM THE NATURAL GAS FEED STREAM**

(71) Applicant: **SHELL OIL COMPANY**, HOUSTON, TX (US)

(72) Inventors: **Uchenna McDonald AGBARAKWE**, Rijswijk (NL); **Mark DEN HEIJER**, Rijswijk (NL)

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(57) **ABSTRACT**

The invention relates to a method and system for cooling a natural gas feed stream and recovering a natural gas liquid stream from the natural gas feed stream using an expansion-based cooling unit and a natural gas liquid removal unit which are integrated. The integration is done by using (part of) a cooling stream from the expansion-based cooling unit to provide cooling duty to the natural gas liquid removal unit.

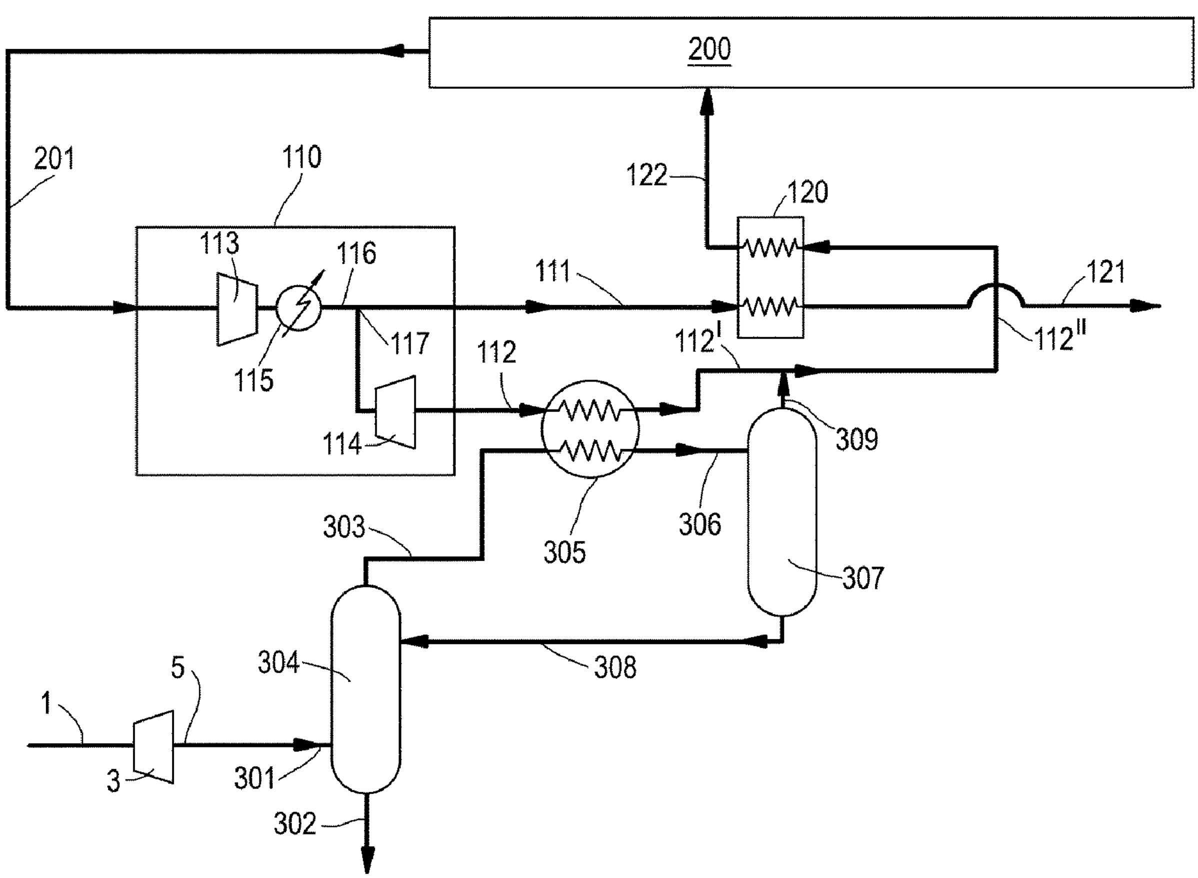
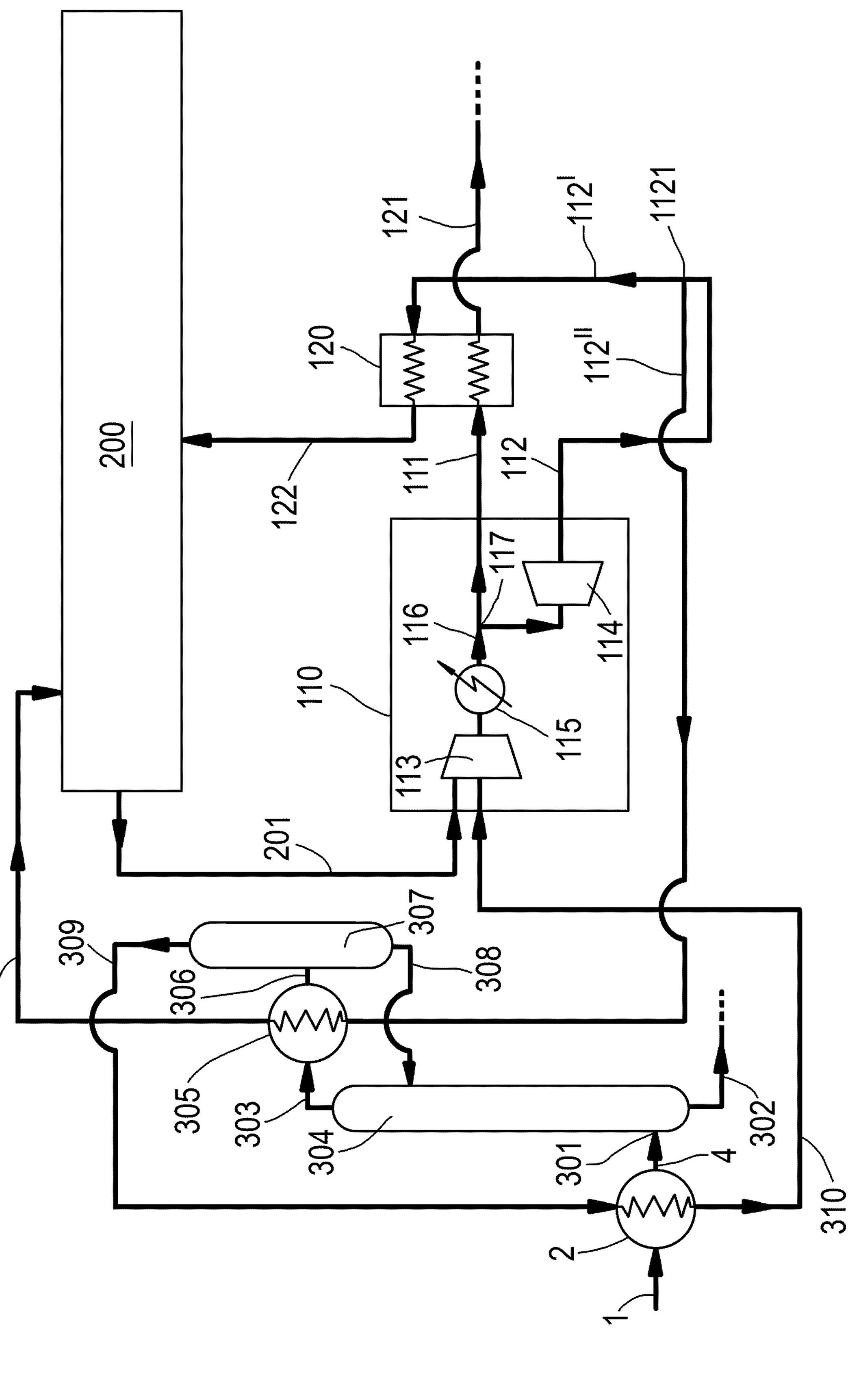


Fig.1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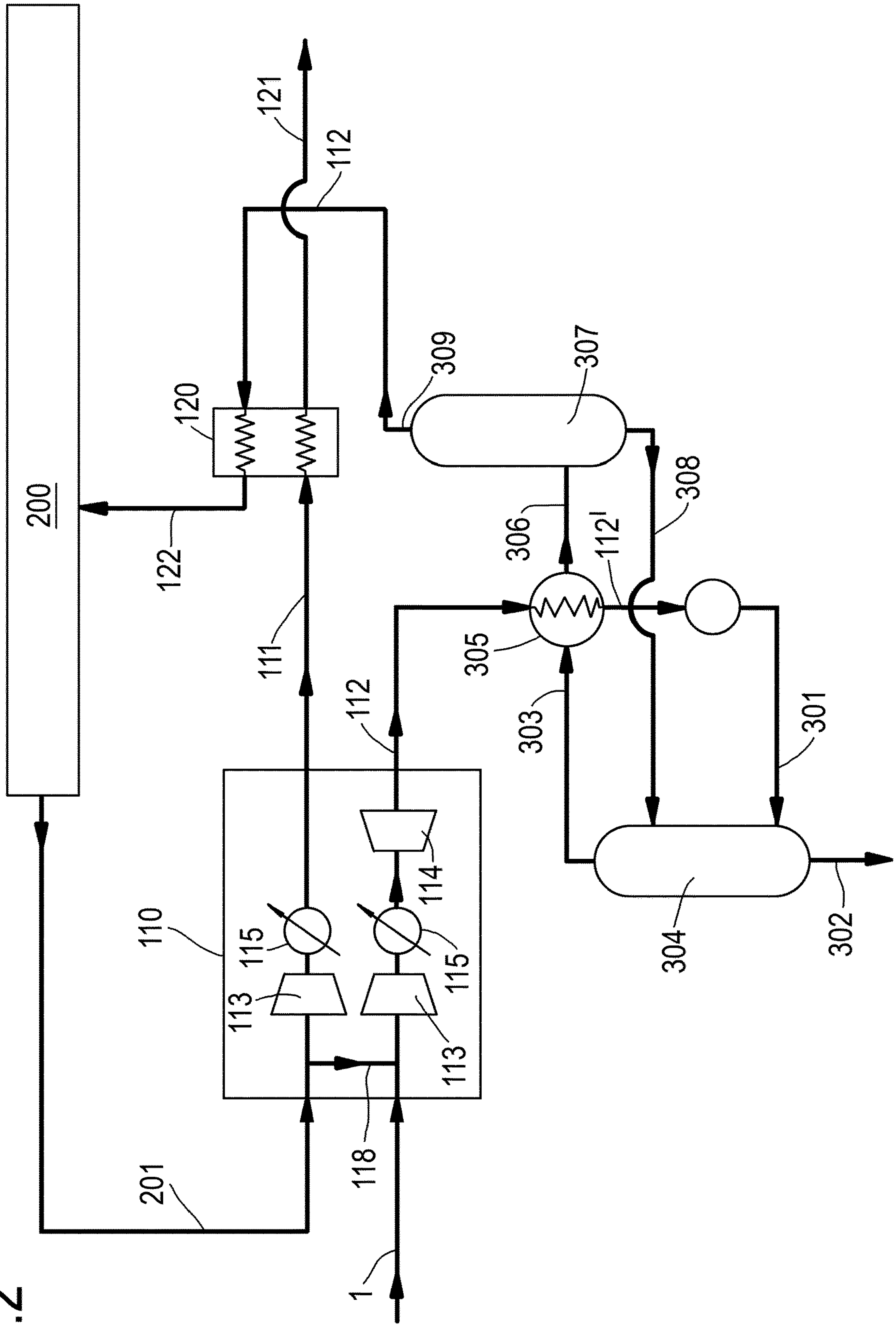
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1
304
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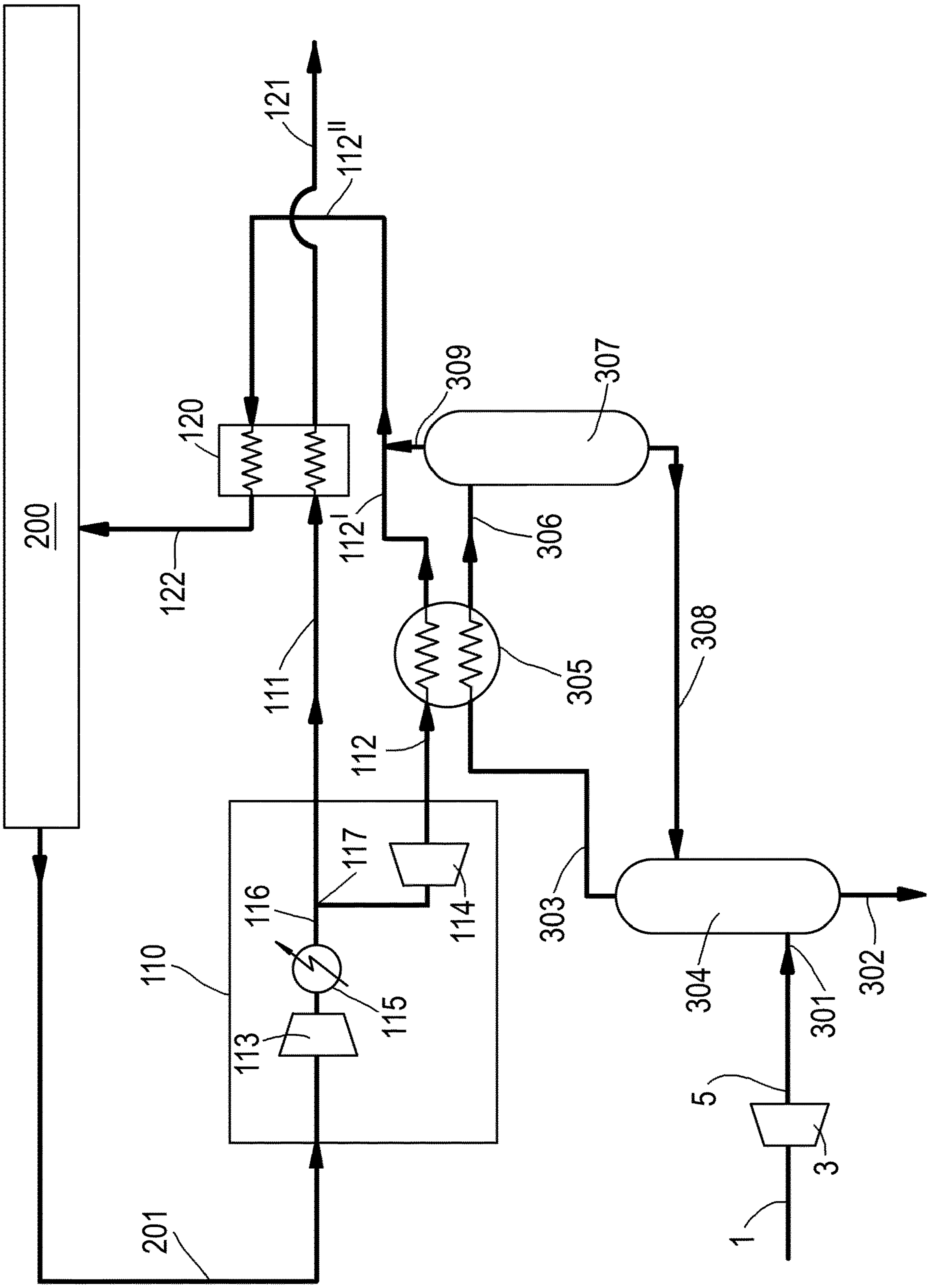
Fig.2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5
3
201
1

Fig.3

METHOD OF COOLING A NATURAL GAS FEED STREAM AND RECOVERING A NATURAL GAS LIQUID STREAM FROM THE NATURAL GAS FEED STREAM

FIELD OF THE INVENTION

[0001] The present invention relates to a method of cooling a natural gas feed stream and recovering a natural gas liquid stream from the natural gas feed stream.

BACKGROUND TO THE INVENTION

[0002] Methods of liquefying hydrocarbon-containing gas streams are well known in the art. It is desirable to liquefy a hydrocarbon-containing gas stream such as a natural gas stream. Natural gas can be stored and transported over long distances more readily as a liquid than in gaseous form, because it occupies a smaller volume and does not need to be stored at high pressures. Typically, before being liquefied, the contaminated hydrocarbon-containing gas stream is treated to remove one or more contaminants (such as H_2O, CO_2, H_2S and the like) which may freeze out during the liquefaction process. Also, heavy hydrocarbons (e.g. $C5^+$-hydrocarbons) are removed to prevent freeze out of those components and to control the composition of the LNG to ensure it meets LNG-specifications (LNG: Liquefied Natural Gas).

[0003] Different processes of cooling and liquefaction are known in which one or more refrigerant cycles with suitable refrigerants are used to cool and liquefy the hydrocarbon-containing gas stream. Examples are a C3-MR (propane-mixed refrigerant) process or a DMR (double mixed refrigerant) process.

[0004] Also, alternative processes are known in no refrigerant cycles are used, such as for instance as described in WO2014/166925.

[0005] These alternative processes may be referred to as expansion based cooling processes, wherein cooling is achieved without the use of separate refrigerants. Instead, cooling is provided by expansion-cooling a split-off stream taken from the natural gas feed stream and using the expansion-cooled split-off stream to cool the remainder of the natural gas feed stream. The natural gas feed stream is preferably provided at a relatively high inlet pressure to obtain efficient expansion-cooling.

[0006] As the inlet pressure is relatively high, for instance above 80 bara, above 100 bara or even above 120 bara, adding an inline $C5^+$-removal unit to the processes is relatively difficult, in particular when the pressure exceeds the critical pressure of the natural gas feed stream. In order to perform $C5^+$-removal, the pressure should then be lowered to below the critical pressure, which negatively influences the efficiency of the expansion based cooling process.

[0007] Alternatively, an upstream $C5^+$-removal unit could be added. This however requires cooling duty and thus the introduction of refrigerants, refrigerant cycles and associated equipment. This increases both the capital expenditures (CAPEX) and operating expenditures (OPEX). It also introduces risks, such as explosion hazards, and logistical challenges, such as the need to have refrigerants available.

[0008] It is an object to provide a method and system to efficiently remove heavy hydrocarbons from a natural gas feed stream and cool the natural gas feed stream by means of an expansion based cooling process.

SUMMARY OF THE INVENTION

[0009] According to an aspect there is provided a method of cooling a natural gas feed stream (**1**) and recovering a natural gas liquid stream (**302**) from the natural gas feed stream (**1**), the method comprising:

a) operating an expansion based cooling unit, comprising

[0010] a1) obtaining a compressed process stream (**111**) and a cooling stream (**112**) from a pressure unit (**110**), both the compressed process stream (**111**) and the cooling stream (**112**) being derived from the natural gas feed stream (**1**),

[0011] a2) passing the compressed process stream (**111**) and at least part of the cooling stream (**112**) to an indirect heat exchanger (**120**) to cool the compressed process stream (**111**) against the at least part of the cooling stream (**112**) to obtain a cooled compressed process stream (**121**) and a warmed cooling stream (**122**),

[0012] a3) recycling the warmed cooling stream (**122**) to the pressure unit (**110**) to be comprised in the compressed process stream (**111**) and/or the cooling stream (**112**),

b) operating a natural gas liquid removal unit, comprising

[0013] b1) passing a feed stream (**301**) being derived from the natural gas feed stream (**1**) to a separation unit (**304**) and obtaining the natural gas liquid stream (**302**) from a lower part of the separation unit (**304**) and a C_5^+ depleted top stream (**303**) from the separation unit (**304**),

[0014] b2) cooling the C_5^+ depleted top stream (**303**) thereby obtaining a cooled C_5^+ depleted top stream (**306**),

[0015] b3) passing the cooled C_5^+ depleted top stream (**306**) to a separation vessel (**307**), thereby obtaining a further gaseous top stream (**309**) and a liquid bottom stream (**308**),

[0016] b4) feeding back the liquid bottom stream (**308**) to an upper part of the separation unit (**304**) as a reflux stream,

[0017] b5) passing the further gaseous top stream (**309**) to the expansion based cooling unit,

[0018] wherein the method comprises cooling the C_5^+ depleted top stream (**303**) in an overhead condenser (**305**) against at least part of the cooling stream (**112**).

[0019] This method provides an efficient combination of an expansion based liquefaction process and a natural gas liquid removal unit, without the need for external or separate refrigerants, refrigerant inventory and refrigerant equipment. An efficient integration is provided in which the challenge of separating heavy hydrocarbons at lower pressure on the one hand and liquefying natural gas by expansion based cooling requiring higher pressure is achieved in an efficient and cost-effective manner. As will become clear from the embodiments provided, there are several ways to implement this method.

[0020] The term C_5^+ depleted top stream is used to indicate that the stream comprises less C_5^+ molecules, expressed in ppm (mol/mol), than the stream it was derived from. So, the C_5^+ depleted top stream (**303**) comprises relatively less C_5^+ molecules than the feed stream (**301**) it was derived from.

[0021] The natural gas liquid stream (**302**) obtained from the lower part of the separation unit (**304**) can be referred to as a C_5^+ enriched stream. The natural gas liquid stream (**302**) is enriched in C_5^+ molecules, expressed in ppm (mol/mol), compared to the stream it was derived from. So, the natural gas liquid stream (**302**) comprises relatively more C_5^+ molecules than the feed stream (**301**) it was derived from.

[0022] The separation unit **304** may be any type of suitable separation unit, such as a fractionation column, a scrub column, a flash vessel, an adsorber or a membrane. It will be understood that the operating pressure or operating pressure window for the separation unit **304** is selected based on the type of separation unit that is used. The natural gas feed stream (**1**) is typically received at a temperature between 0° C. and 35° C. and a pressure between 1 and 90 bara.

[0023] The overhead condenser (**305**) may be an indirect heat exchanger.

[0024] The cooled compressed process stream (**121**) obtained may be subject to further cooling and processing and may at least partially be liquefied, to obtain liquefied natural gas. The liquefied natural gas may be passed to a storage tank.

Embodiment 1

[0025] According to an embodiment there is provided a method according to claim **1**, the method further comprising:

[0026] cooling the natural gas feed stream (**1**) in an inlet heat exchanger (**2**) against the further gaseous top stream (**309**) obtained from the separation vessel (**307**) to obtain a cooled natural gas feed stream (**4**) and a warmed further gaseous top stream (**310**),

[0027] passing the cooled natural gas stream (**4**) to the separation unit (**304**) thereby providing the feed stream (**301**).

[0028] According to an embodiment

[0029] a1) further comprises passing the warmed further gaseous top stream (**310**) to the pressure unit (**110**) to be part of the compressed process stream (**111**) and/or the cooling stream (**112**),

[0030] a2) further comprises splitting the cooling stream (**112**) in a first cooling stream portion (**112'**) and a second cooling stream portion (**112"**), wherein the at least part of the cooling stream passed to the indirect heat exchanger (**120**) is formed by the first cooling stream portion (**112'**) and

[0031] wherein cooling the C_5^+ depleted top stream (**303**) in the indirect heat exchanger (**305**) is done against the second cooling stream portion (**112"**), thereby obtaining a warmed second cooling stream portion (**112'"**).

[0032] According to a further embodiment, the warmed cooling stream (**122**) and the warmed second cooling stream portion (**112'"**) are passed to a recompression unit (**200**).

[0033] A warmed second cooling stream portion (**112'"**) is obtained from the indirect heat exchanger (**305**), which is passed to a recompression unit. The warmed cooling stream (**122**) obtained from the indirect heat exchanger is also passed to the recompression unit (**200**). The recompression unit (**200**) is arranged to generate a recycle stream which is passed to the pressure unit (**110**) to be part of the compressed process stream (**111**) and the cooling stream (**112**).

Embodiment 2

[0034] According to an embodiment there is provided a method according to claim **1**, wherein cooling the C_5^+ depleted top stream (**303**) is done in the overhead condenser (**305**) against the cooling stream (**112**), thereby obtaining a warmed cooling stream (**112'**), and wherein

[0035] a1) further comprises feeding the natural gas feed stream (**1**) and a recycle stream (**201**) to the pressure unit (**110**), and wherein the method comprises:

[0036] passing the warmed cooling stream (**112'**) to the separation unit (**304**) thereby providing the feed stream (**301**) to the separation unit (**304**),

[0037] passing the further gaseous top stream (**309**) obtained in b3) to the indirect heat exchanger (**120**) thereby providing the at least part of the cooling stream (**112**) which is passed to the indirect heat exchanger (**120**) in a2) and

[0038] passing the warmed cooling stream (**122**) which is obtained in a2) to a recompression unit (**200**) to obtain the recycle stream (**201**).

[0039] Cooling the C_5^+ depleted top stream (**303**) in the overhead condenser (**305**) against the cooling stream (**112**) is preferably done against the complete cooling stream (**112**).

Embodiment 3

[0040] According to an embodiment there is provided a method according to claim **1**, the method further comprising:

[0041] expanding the natural gas feed stream (**1**) in an inlet expander (**3**) to obtain an expanded natural gas feed stream (**5**) and

[0042] passing the expanded natural gas feed stream (**5**) to the separation unit (**304**) thereby providing the feed stream (**301**) to the separation unit (**304**).

[0043] The natural gas feed stream (**1**) is typically received at a temperature between 0° C. and 35° C. and a pressure between 1 and 90 bara. The expanded natural gas feed stream (**5**) is typically at a temperature between −35° C. and −70° C. and a pressure.

[0044] According to an embodiment cooling the C_5^+ depleted top stream (**303**) is done in the overhead condenser **305** against the entire cooling stream (**112**) or part of the cooling stream, in both situations a warmed cooling stream (**113'**) is obtained which is passed to the indirect heat exchanger (**120**) in a2).

[0045] According to a further embodiment cooling the C_5^+ depleted top stream (**303**) in the overhead condenser (**305**) is done against the entire cooling stream (**112**) or part of the cooling stream, thereby obtaining a warmed cooling stream (**112'**), the method further comprising

[0046] passing the further gaseous top stream (**309**) to the expansion based cooling unit comprises combining the further gaseous top stream (**309**) with the warmed cooling stream (**112'**) to obtain a combined stream (**112"**) and passing the at least part of the cooling stream (**112**) to the indirect heat exchanger (**120**) in a2) is done by passing the combined stream (**112"**) to the indirect heat exchanger (**120**).

[0047] According to a further aspect there is provided a system for cooling a natural gas feed stream (**1**) and recovering a natural gas liquid stream (**302**) from the natural gas feed stream (**1**), the system comprising an expansion based cooling unit, wherein the expansion based cooling unit comprises:

[0048] a pressure unit (**110**) which is arranged to receive at least a recycle stream (**201**) and generate and discharge a compressed process stream (**111**) and a cooling stream (**112**),

[0049] an indirect heat exchanger (**120**) fluidly connected to the pressure unit (**110**) to receive the compressed process stream (**111**) and the cooling stream (**112**) to cool the compressed process stream (**111**) against the at least part of the cooling stream (**112**) thereby obtaining a cooled compressed process stream (**121**) and a warmed cooling stream (**122**),

[0050] the system further comprising a recompression unit (**200**) being fluidly connected to the expansion based cooling unit to receive and compress at least the warmed cooling stream (**122**), the recompression unit (**200**) being arranged to discharge the recycle stream (**201**), which is at least partially derived from the warmed cooling stream (**122**), the recompression unit (**200**) being in fluid communication with the pressure unit (**110**),

wherein the system further comprises a natural gas liquid removal unit, the natural gas liquid removal unit comprising

[0051] a separation unit (**304**) arranged to receive a feed stream (**301**) and separate the feed stream (**301**) to obtain and discharge a natural gas liquid stream (**302**) and a C_5^+ depleted top stream (**303**),

[0052] an overhead condenser (**305**) fluidly connected to the separation unit (**304**) to receive the C_5^+ depleted top stream (**303**) and fluidly connected to the expansion based cooling unit to receive at least part of the cooling stream (**112**) to cool the C_5^+ depleted top stream (**303**) against the at least part of the cooling stream (**112**) thereby obtaining a cooled C_5^+ depleted top stream (**306**),

[0053] a separation vessel (**307**) fluidly connected to the overhead condenser (**305**) to receive the cooled C_5^+ depleted top stream (**306**) and separate the cooled C_5^+ depleted top stream (**306**) to obtain and discharge a further gaseous top stream (**309**) and a liquid bottom stream (**308**), wherein the separation vessel (**307**) is fluidly connected to an upper part of the separation unit (**304**) to feed back the liquid bottom stream (**308**) to the upper part of to the separation unit (**304**) as a reflux stream, wherein the separation vessel (**307**) is fluidly connected to the expansion based cooling unit.

[0054] According to an embodiment the pressure unit (**110**) is arranged to receive the natural gas feed stream **1** directly. According to alternative embodiments the natural gas feed stream is fed to the natural gas liquid removal unit.

BRIEF DESCRIPTION OF THE DRAWINGS

[0055] The drawing figures depict one or more implementations in accordance with the present teachings, by way of example only, not by way of limitation. In the figures, like reference numerals refer to the same or similar elements.

[0056] FIG. **1** provides a schematic illustration of an embodiment,

[0057] FIG. **2** provides a schematic illustration of an alternative embodiment, and

[0058] FIG. **3** provides a schematic illustration of yet a further alternative embodiment.

DETAILED DESCRIPTION OF THE INVENTION

[0059] There is provided a method and system for cooling a natural gas feed stream and recovering a natural gas liquid stream from the natural gas feed stream using an expansion based cooling unit and a natural gas liquid removal unit which are integrated. The integration is done by using (part of) a cooling stream from the expansion based cooling unit to provide cooling duty to the natural gas liquid removal unit. Below, different embodiments will be described in more detail, showing that different types of integration are possible.

[0060] According to an embodiment there is provided a method of cooling a natural gas feed stream **1** and recovering a natural gas liquid stream **302** from the natural gas feed stream **1**, the method comprising:

[0061] operating an expansion based cooling unit, comprising deriving a process stream **111** and a cooling stream **112** from the natural gas feed stream **1** and cooling the process stream **111** against at least part of the cooling stream, and

[0062] operating a natural gas liquid removal unit, comprising passing a feed stream **301** being derived from the natural gas feed stream **1** to a separation unit **304**, the natural gas liquid removal unit comprises passing a reflux stream to an upper part of the separation unit **304** as a reflux stream **308**, wherein at least part of the cooling stream **112** is used to provide cooling duty to the natural gas liquid removal unit to obtain the reflux stream.

[0063] The term expansion based cooling unit is used to refer to cooling units in which cooling is achieved by expansion-cooling a first natural gas stream thereby obtaining a cooling stream **112** and wherein the cooling stream **112** is used to cool a further natural gas stream (compressed process stream **111**). Both the first and the second natural gas stream are derived from the natural gas feed stream **1**. Both the compressed process stream **111** and at least part of the cooling stream **112** are passed to an indirect heat exchanger **120** to cool the compressed process stream **111** against the at least part of the cooling stream **112** to obtain a cooled compressed process stream **121** and a warmed cooling stream **122**. The warmed cooling stream **122** is fed back to the pressure unit **110**.

[0064] The pressure unit **110** is arranged to discharge the compressed process stream **111** at a relatively high pressure (e.g. above 80, 100 or even 120 bara). Also, the cooling stream **112** is compressed by one or more compressors (optionally having an after-cooler) to a relatively high pressure (e.g. above 80, 100 or even 120 bara) to allow efficient expansion cooling over a valve or expander **114**.

[0065] The expansion based cooling schemes as depicted in the figures and explained in the description below show one expansion-cooling stage, but it will be understood that additional expansion-cooling stages may be present in which further split-off streams are obtained and used for cooling. Such additional expansion-cooling stages may be positioned downstream of the expansion-cooling stage shown in the figures.

[0066] It will be understood that variations to the expansion based cooling unit are conceivable. For instance, the cooled compressed process stream **121** may be passed on to a further expansion-cooling stage in which a first part of the cooled compressed process stream **121** is expansion-cooled and used to further cool a remainder of the cooled compressed process stream **121**.

[0067] Further equipment, such as an end-flash unit, may be available as will be understood by the skilled person.

[0068] The expansion based cooling unit is arranged to discharge a liquefied natural gas stream. The expansion based cooling unit may be fluidly connected to one or more LNG storage tanks to store the cooled and liquefied natural gas.

[0069] According to the embodiments described in more detail below with reference to the different figures, a natural gas liquid stream **302** is obtained from a natural gas feed stream **1** and a natural gas feed stream **1** is cooled using an expansion based cooling unit. The natural gas liquids may be subject to further processing and separation.

[0070] A pressure unit **110** is provided comprising one or more compressors **113** and optionally one or more intercoolers **115** positioned downstream of the compressor **113**. It will be understood that the amount of compressors **113** and aftercoolers **115** shown in the Figures is only by way of example and that there may be provided a plurality of parallel and/or serial positioned (intercooled) compressors. A compressed stream **116** is hereby obtained. The compressed stream **116** may have a pressure above 80 bara, above 100 bara or even above 120 bara.

[0071] The pressure unit **110** may further comprise a splitter **117** to split the compressed stream **116** into a first part referred to as the compressed process stream **111** and a second part which is passed through a valve or expander **114** (optionally being a Joule-Tompson valve) thereby obtaining cooling stream **112**. Both the compressed process stream and the cooling stream **112** are derived from the natural gas feed stream **1** as will be explained in more detail below. The splitter **117** may be a controllable splitter to control the relative flow rates of the compressed process stream **111** and the cooling stream **112**.

[0072] The embodiment described with reference to FIG. **2** has a different set-up as will be explained in more detail below with reference to FIG. **2**.

[0073] The cooling stream **112** is at a lower pressure and at a lower temperature than the compressed process stream **111**. For instance, the pressure of the cooling stream **112** may be 60-90 bar lower than the pressure of the compressed process stream **111** and the temperature of the cooling stream **112** may be 50-90° C. lower than the temperature of the compressed process stream **111**.

[0074] The expansion based cooling unit further comprises an indirect heat exchanger **120** arranged to receive via a first inlet the compressed process stream **111** and via a second inlet at least part of the cooling stream **112** and allow these streams to exchange heat. It will be understood that although the indirect heat exchanger **120** is schematically shown as a single heat exchanger it may in practice comprise several units positioned parallel and/or in series with respect to each other. The indirect heat exchanger **120** may be any suitable type of indirect heat exchanger, such as a coil wound heat exchanger. The term indirect heat exchanger **120** is used to refer to heat exchangers in which the streams that exchange heat do not mix and are not in direct contact with each other.

[0075] The indirect heat exchanger **120** discharges via a first outlet a cooled compressed process stream **121** and via a second outlet a warmed cooling stream **122**. The cooled compressed process stream **121** may be at a slightly lower pressure than compressed stream **116** (e.g. 1-4 bar lower), and may have a temperature below minus 30° C.

[0076] Further provided is a recompression unit **200**, which is depicted schematically only. The recompression unit **200** comprises one or more compressors able to receive one or more streams and generate and discharge a recycle stream **201** and pass the recycle stream back to the pressure unit **110**. The one or more compressors may be positioned in series and may comprise intercoolers. Furthermore, split off streams may be taken form the recompression unit **200** for other purposes, such as for fuel. The warmed cooling stream **122** is passed to the recompression unit **200** to be recompressed and passed back to the pressure unit **110**. It will be understood that the recompression unit **110** may receive additional streams not indicated in the Figures.

[0077] The embodiments further comprise a natural gas liquid removal unit equipped to perform actions b1)-b5) as described above.

[0078] The natural gas liquid removal unit comprises a separation unit **304**, an overhead condenser **305** and a separation vessel **307**.

[0079] The top of the separation unit **304** is fluidly connected to the separation vessel **307** via the overhead condenser **305**. In use, a C_5^+ depleted top stream **303** is obtained from the separation unit **304** and passed to the separation vessel **307** via the overhead condenser **305**. The overhead condenser **305** comprises a first inlet to receive the C_5^+ depleted top stream **303** and a first outlet to discharge the cooled C_5^+ depleted top stream **306**. The C_5^+ depleted top stream **303** is cooled in the overhead condenser **304**, thereby obtaining a cooled C_5^+ depleted top stream **306** which is passed on to the separation vessel **307**.

[0080] The bottom of the separation unit **304** comprises an outlet to discharge a natural gas liquid stream **302** from the separation unit **304**.

[0081] The separation vessel **307** comprises a top outlet to discharge a further gaseous top stream **309** and a bottom outlet to discharge a liquid bottom stream **308**, which bottom outlet is in fluid communication with an upper part of the separation unit **304** to pass back the liquid bottom stream **308** to the separation unit **304**, thereby providing a reflux stream.

[0082] The top outlet of the separation vessel **307** is in fluid communication with the expansion based cooling unit to pass the further gaseous top stream **309** to the expansion based cooling unit.

[0083] The overhead condenser **305** further comprises a second inlet to receive at least part of the cooling stream **112** to provide cooling duty to the C_5^+ depleted top stream **303** and a second outlet to discharge the warmed second cooling stream portion **112'''** or the warmed cooling stream **112'** (depending on the embodiment).

[0084] The difference between the different embodiments is mainly in the natural gas liquid removal units, so these will be explained in more detail below with reference to the different Figures.

Embodiment 1—FIG. **1**

[0085] According to the first embodiment schematically depicted in FIG. **1**, the natural gas feed stream **1** is first passed through an inlet heat exchanger **2** to allow the natural gas feed stream **1** to be cooled against the above mentioned further gaseous top stream **309**. The inlet heat exchanger **2** is an indirect heat exchanger, comprising a first inlet to receive the natural gas feed stream **1** and a first outlet to discharge a cooled natural gas feed stream **4**. The cooled natural gas feed stream **4** may have a temperature in the range of minus 10° C.-minus 30° C., where the natural gas feed stream **1** may have a temperature in the range of 5° C.-25° C.

[0086] The inlet heat exchanger **2** further comprises a second inlet to receive the further gaseous top stream **309** and a second outlet to discharge a warmed further gaseous top stream **310**. The first outlet of the inlet heat exchanger **2** is in fluid communication with the separation unit **304** to provide the cooled natural gas feed stream **4** to the separation unit **304**, forming the feed stream **301** mentioned above.

[0087] The pressure of the cooled natural gas feed stream **20** as well as the pressure in the separation unit **304** may be in the range of 50-60 bara.

[0088] FIG. **1** further shows that the second outlet of the inlet heat exchanger **2** is in fluid communication with the pressure unit **110** to pass the warmed further gaseous top stream **310** to an inlet of the pressure unit **110** and to compressor **113**.

[0089] FIG. **1** further shows a splitter **1121** being in fluid communication with the pressure unit **110** to receive cooling stream **112** and split cooling stream **112** in a first cooling stream portion **112'** and a second cooling stream portion **112"**. The first cooling stream portion **112'** is passed to the second inlet of the indirect heat exchanger **120**. The second cooling stream portion **112"** is passed to the second inlet of the overhead condenser **305**. The overhead condenser **305** comprises a second outlet which is in fluid communication with the recompression unit **200** to pass the warmed second cooling stream portion **112'"** to the recompression unit **200**.

[0090] The cooling stream **112** and first and second cooling stream portions **112'**, **112"** may be at a temperature in the range of minus 50° C.-minus 60° C. and at a pressure in the range of 30-50 bara.

Embodiment 2—FIG. **2**

[0091] According to a second embodiment the natural gas feed stream **1** is passed into the pressure unit **110** together with a recycle stream **201** obtained from the recompression unit **200**.

[0092] The pressure unit **110** as schematically depicted in FIG. **2** is a variant to the pressure unit **110** depicted in FIG. **1** and comprises two parallel compressors **113** with associated intercoolers **115** positioned downstream of the respective compressors **113**. Again, it will be understood that each compressor **113** as shown in FIG. **2** may in fact be formed by multiple (intercooled) compressors, positioned in series and/or parallel with respect to each other.

[0093] A first compressor **113** is arranged to receive the natural gas feed stream **1**, a second compressor **113** is arranged to receive the recycle stream **201**. However, upstream of the compressors **113** there may be provided a cross-connection to obtain a split recycle gas stream **118** to be added to the natural gas feed stream **1**, thereby allowing to balance the flow rates between the two parallel compressors **113** as well as providing the option to control the composition of the cooling stream **112**. Controllable valves (not shown) may be provided to control the flow through the cross-connection **118**.

[0094] As mentioned above, the overhead condenser **305** comprises a second inlet to receive at least part of the cooling stream **112**. According to the embodiment depicted in FIG. **2** the second inlet is in fluid communication with the pressure unit **110** to receive the full cooling stream **112**.

[0095] The overhead condenser **305** allows the at least part of the cooling stream **112** to cool the C_5^+ depleted top stream **303** thereby obtaining a cooled C_5^+ depleted top stream **306** and a warmed cooling stream **112'**. The overhead condenser **305** comprises a second outlet to discharge the warmed cooling stream **112'**. The second outlet of the overhead condenser **305** is in fluid communication with a bottom part of the separation unit **304** to provide the separation unit **304** with the feed stream **301**.

[0096] The top of the separation vessel **307** is in fluid communication with the second inlet of the indirect heat exchanger **120** to pass the further gaseous top stream **309** (obtained in b3) to the indirect heat exchanger **120** thereby providing the at least part of the cooling stream **112** which is passed to the indirect heat exchanger **120** (as indicated in a2). The second outlet of the indirect heat exchanger **120** is in fluid communication with the recompression unit to pass the warmed cooling stream **122** to the recompression unit **200**.

[0097] In this second embodiment schematically depicted in FIG. **2**, heavy hydrocarbon separation which takes place in the natural gas liquid removal unit, is done at a relatively low pressure, i.e. after gas expansion in valve or expander **114**. The pressure in the separation unit **304** may be in the range of 35-45 bara (which is lower than in the first embodiment).

[0098] The natural gas feed stream **1** being received from a gas conditioning or gas processing section (not shown) is first mixed with a split recycle gas stream **118**, compressed to relatively high pressure, e.g. above 80 bara, 100 bara or 120 bar and expanded in valve or expander **114**. The relatively cool cooling stream **112** from the valve or expander **114** provides cooling for the overhead condenser **305**, before undergoing separation in the natural gas liquid removal unit. The treated gas (top outlet of the separation vessel **307**) is allowed to exchange cold with the compressed process stream **111**, which is also at a relatively high pressure, i.e. substantially equal to the e.g. 120 bar.

Embodiment 3—FIG. **3**

[0099] According to a third embodiment the natural gas feed stream **1** is passed into an inlet expander **3** to allow the natural gas feed stream **1** to expand, thereby obtaining an expanded natural gas feed stream **5**. The outlet of the inlet expander **3** is in fluid communication with an inlet at of the separation unit **304** to pass the expanded natural gas feed stream **5** to the separation unit, thereby providing the above mentioned feed stream **301** to the separation unit **304**.

[0100] The natural gas feed stream **1** is typically received at a temperature between 0° C. and 35° C. and a pressure between 1 and 90 bara. The expanded natural gas feed stream **5** is typically at a temperature between −35° C. and −70° C. and a pressure may be in the range of 30-50 bara.

[0101] The pressure unit **110** is similar as in the first embodiment described above with reference to FIG. **1**.

[0102] The C_5^+ depleted top stream **303** obtained from the top of the separation unit **304** is passed to the first inlet of the overhead condenser **305** and the cooling stream **112** is passed to the second inlet of the overhead condenser **305**, thereby obtaining a warmed cooling stream **112'** from the second outlet of the overhead condenser **305**. The second outlet of the overhead condenser **305** is in fluid communication with the second inlet of the indirect heat exchanger **120** to pass the warmed cooling stream **112'** to the indirect heat exchanger **120**.

[0103] Furthermore, the separation vessel **307** is in fluid communication with the warmed cooling stream **112'** to combine the warmed cooling stream **112** with the further gaseous top stream **309** thereby obtaining a combined stream **112** which is passed to the second inlet of the indirect heat exchanger.

[0104] The above embodiments provide the advantage that no external refrigerants are needed including the associated supply and storage costs.

[0105] Embodiment 1 prevents enrichment of C_5^+ liquid in the final LNG stream when compared to the composition exiting the separation unit **304** (being a scrub column), due to treatment taking place before liquefaction.

[0106] Embodiments 2 and 3 provide the advantage that the recycle flows are lower compared to embodiment 1, therefore requiring less power for flash gas recompression and recycling.

[0107] From simulation studies, all 3 embodiments showed a specific power consumption lower than 285 kW/tLNG (11.9 kW/tpd).

[0108] It is noted that the pressure and temperature ranges as mentioned above are based on the use of a scrub column for separation unit **304**. Operating conditions may be different for other equipment is used, such as a fractionation column, a flash vessel, an adsorber or a membrane. Embodiments 1, 2 and 3 can treat and liquefy average and rich feed gas effectively and also some lean gas composition. For a very lean feed gas, a different choice might be made for separation unit **304** for the actual separation equipment (a fractionation column, a flash vessel, an adsorber or a membrane) or a combination of equipment to achieve natural gas liquefaction.

[0109] The person skilled in the art will readily understand that many modifications may be made without departing from the scope of the invention. Where the word step(s) or action(s) is used in this text with reference to a method or process, it will be understood that this is not done to imply a specific order (in time). The steps/actions may be applied in any suitable order, including simultaneously. Also, the steps/actions are not limited to the examples provided thereof in the description.

1. A method of cooling a natural gas feed stream and recovering a natural gas liquid stream from the natural gas feed stream, the method comprising:

a) operating an expansion based cooling unit, comprising obtaining a cooling stream being derived from the natural gas feed stream,

b) operating a natural gas liquid removal unit, comprising passing a feed stream being derived from the natural gas feed stream to a separation unit and obtaining a C_5^+ depleted top stream from the separation unit,

wherein the method comprises cooling the C_5^+ depleted top stream in an overhead condenser against at least part of the cooling stream.

2. The method according to claim **1** comprising:

a) operating an expansion based cooling unit, comprising

a1) obtaining a compressed process stream and a cooling stream from a pressure unit, both the compressed process stream and the cooling stream being derived from the natural gas feed stream,

a2) passing the compressed process stream and at least part of the cooling stream to an indirect heat exchanger to cool the compressed process stream against the at least part of the cooling stream to obtain a cooled compressed process stream and a warmed cooling stream,

a3) recycling the warmed cooling stream to the pressure unit to be comprised in the compressed process stream and/or the cooling stream,

b) operating a natural gas liquid removal unit, comprising

b1) passing a feed stream being derived from the natural gas feed stream to a separation unit and obtaining the natural gas liquid stream from a lower part of the separation unit and a C_5^+ depleted top stream from the separation unit,

b2) cooling the C_5^+ depleted top stream thereby obtaining a cooled C_5^+ depleted top stream,

b3) passing the cooled C_5^+ depleted top stream to a separation vessel, thereby obtaining a further gaseous top stream and a liquid bottom stream,

b4) feeding back the liquid bottom stream to an upper part of the separation unit as a reflux stream,

b5) passing the further gaseous top stream to the expansion based cooling unit,

wherein the method comprises cooling the C_5^+ depleted top stream in an overhead condenser against at least part of the cooling stream.

3. The method according to claim **1**, further comprising:

expanding the natural gas feed stream in an inlet expander to obtain an expanded natural gas feed stream and

passing the expanded natural gas feed stream to the separation unit thereby providing the feed stream to the separation unit.

4. The method according to claim **3**, wherein cooling the C_5^+ depleted top stream in the overhead condenser is done against the entire cooling stream or part of the cooling stream, thereby obtaining a warmed cooling stream, the method further comprising the steps of:

passing the further gaseous top stream to the expansion based cooling unit comprises combining the further gaseous top stream with the warmed cooling stream to obtain a combined stream and passing the at least part of the cooling stream to the indirect heat exchanger in a2) is done by passing the combined stream to the indirect heat exchanger.

5. The method according to claim **1**, wherein:

a1) further comprises passing the warmed further gaseous top stream to the pressure unit to be part of the compressed process stream and/or the cooling stream;

a2) further comprises splitting the cooling stream in a first cooling stream portion and a second cooling stream portion, wherein the at least part of the cooling stream passed to the indirect heat exchanger is formed by the first cooling stream portion; and

wherein cooling the C_5^+ depleted top stream in the indirect heat exchanger is done against the second cooling stream portion, thereby obtaining a warmed second cooling stream portion.

6. The method according to claim **1**, further comprising the steps of:

cooling the natural gas feed stream in an inlet heat exchanger against the further gaseous top stream obtained from the separation vessel to obtain a cooled natural gas feed stream and a warmed further gaseous top stream,

passing the cooled natural gas stream to the separation unit thereby providing the feed stream.

7. The method according to claim **1**, wherein the warmed cooling stream and the warmed second cooling stream portion are passed to a recompression unit.

8. The method according to claim **1**, wherein cooling the C_5^+ depleted top stream is done in the overhead condenser against the cooling stream, thereby obtaining a warmed cooling stream, and wherein:

a1) further comprises feeding the natural gas feed stream and a recycle stream to the pressure unit,

and wherein the method comprises the steps of:

passing the warmed cooling stream to the separation unit thereby providing the feed stream to the separation unit;

passing the further gaseous top stream obtained in b3) to the indirect heat exchanger thereby providing the at least part of the cooling stream which is passed to the indirect heat exchanger in a2); and

passing the warmed cooling stream which is obtained in a2) to a recompression unit to obtain the recycle stream.

9. A system for cooling a natural gas feed stream and recovering a natural gas liquid stream from the natural gas feed stream, the system comprising an expansion based cooling unit arranged to generate a cooling stream and a natural gas liquid removal unit comprising a separation unit arranged to discharge a C_5^+ depleted top stream,

wherein the system further comprises an overhead condenser fluidly connected to the separation unit to receive the C_5^+ depleted top stream and fluidly connected to the expansion based cooling unit to receive at least part of the cooling stream to cool the C_5^+ depleted top stream against the at least part of the cooling stream.

10. The system according to claim **9**, comprising an expansion based cooling unit, wherein the expansion based cooling unit comprises:

a pressure unit which is arranged to receive at least a recycle stream and generate and discharge a compressed process stream and a cooling stream,

an indirect heat exchanger fluidly connected to the pressure unit to receive the compressed process stream and the cooling stream to cool the compressed process stream against the at least part of the cooling stream thereby obtaining a cooled compressed process stream and a warmed cooling stream,

the system further comprising a recompression unit being fluidly connected to the expansion based cooling unit to receive and compress at least the warmed cooling stream, the recompression unit being arranged to discharge the recycle stream, which is at least partially derived from the warmed cooling stream, the recompression unit being in fluid communication with the pressure unit,

wherein the system further comprises a natural gas liquid removal unit, the natural gas liquid removal unit comprising

a separation unit arranged to receive a feed stream and separate the feed stream to obtain and discharge a natural gas liquid stream and a C_5^+ depleted top stream,

an overhead condenser fluidly connected to the separation unit to receive the C_5^+ depleted top stream and fluidly connected to the expansion based cooling unit to receive at least part of the cooling stream to cool the C_5^+ depleted top stream against the at least part of the cooling stream thereby obtaining a cooled C_5^+ depleted top stream, and

a separation vessel fluidly connected to the overhead condenser to receive the cooled C_5^+ depleted top stream and separate the cooled C_5^+ depleted top stream to obtain and discharge a further gaseous top stream and a liquid bottom stream, wherein the separation vessel is fluidly connected to an upper part of the separation unit to feed back the liquid bottom stream to the upper part of to the separation unit as a reflux stream, wherein the separation vessel is fluidly connected to the expansion based cooling unit.

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