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(54) LIQUID NATURAL GAS REGASIFICATION PROCESSES AND SYSTEMS

(57) A liquid natural gas (LNG) regasification process comprising a single column demethanizer process is provided. The process comprises introducing a rich LNG feed stream, comprising a mixture of at least methane and ethane, in an at least partially vaporized state into a demethanizer; condensing an overhead stream from the demethanizer, wherein the overhead stream comprises a lean LNG enriched in methane and reduced in ethane relative to the rich LNG feed stream; collecting the lean LNG in a collection chamber; operating the LNG regasification process in a first operating state in which a lean LNG sendout stream is delivered to a sendout pipeline, wherein the lean LNG sendout stream comprises at least a portion of the lean LNG; and carrying out a heat exchange process comprising heat exchange between the lean LNG sendout stream and the overhead stream, such that the LNG sendout stream is heated and the overhead stream collected from the demethanizer is condensed.

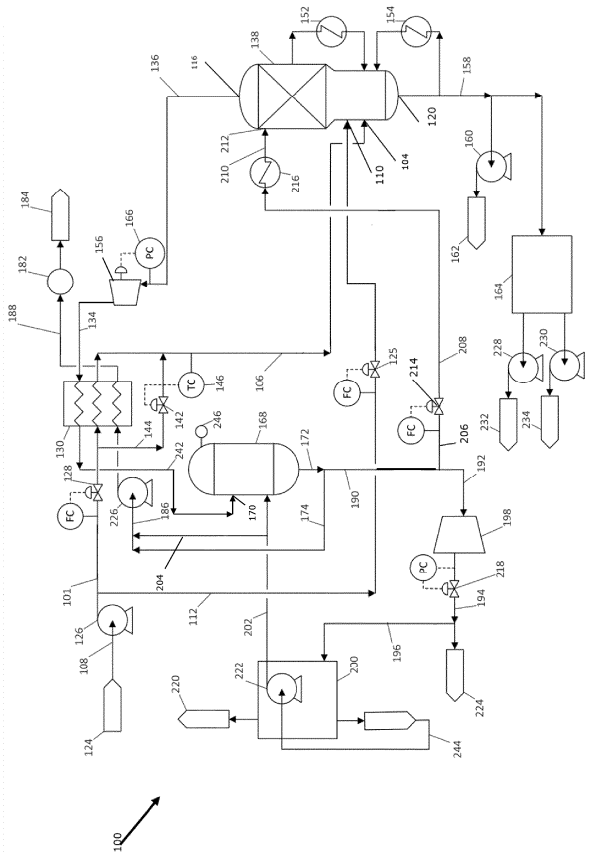


Figure 1

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Description

Technical Field

[0001] The present disclosure relates to liquid natural gas (LNG) regasification processes and systems. More particularly although not necessarily exclusively to LNG regasification processes and systems using a single-column demethanizer process to separate methane from ethane and other heavier hydrocarbons.

Background

[0002] Natural gas can be transported and stored as liquid natural gas (LNG), such as for long distance transportation and/or when a pipeline is not a viable option for transportation. Cooling natural gas down to a temperature in the range of approximately -155 °C to - 170°C condenses it into LNG and reduces its volume approximately 600 fold from its gaseous state.

[0003] Regasification is the process of converting LNG back to its gaseous state. Regasification systems and processes are typically located at an import terminal where an LNG carrier (a tank ship designed for transporting LNG) unloads the LNG for regasification.

Summary

[0004] In an aspect of the disclosure, a liquid natural gas (LNG) regasification process is provided, comprising a single column demethanizer process, comprising:

a. introducing a rich LNG feed stream, comprising a mixture of at least methane and ethane, in an at least partially vaporized state into a demethanizer;
b. condensing an overhead stream from the demethanizer, wherein the overhead stream comprises a lean LNG enriched in methane and reduced in ethane relative to the rich LNG feed stream;
c. collecting the lean LNG in a collection chamber

[0005] Optionally, the collection chamber serves as a suction drum, such that the suction drum serves to protect downstream equipment (e.g. rotating equipment).

[0006] In other words, only one demethanizer column is provided in the process.

[0007] Put another way, the flow of the rich LNG feed stream to the demethanizer passes from a feed inlet to the demethanizer, without the feed stream first passing through other distillation or component separation equipment (e.g. without passing through a second demethanizer, absorber or other equipment that acts to remove methane). Further, the flow of lean LNG passes from the overhead stream from the demethanizer to the sendout pipeline, without first combining with a lean LNG stream from other distillation or component separation equipment (e.g. without combining with a lean LNG stream from a second demethanizer, absorber or other equipment that acts to remove methane).

[0008] In an aspect of the disclosure, a liquid natural gas (LNG) regasification process comprising a single column demethanizer process is provided, the process comprising:

a. introducing a rich LNG feed stream, comprising a mixture of at least methane and ethane, in an at least partially vaporized state into a demethanizer;
b. condensing an overhead stream from the demethanizer, wherein the overhead stream comprises a lean LNG enriched in methane and reduced in ethane relative to the rich LNG feed stream;
c. collecting the lean LNG in a collection chamber;
d. operating the LNG gasification process in a first operating state, in which a lean LNG sendout stream is delivered to a sendout pipeline, wherein the lean LNG sendout stream comprises at least a portion of the lean LNG; and
e. carrying out a heat exchange process comprising heat exchange between the lean LNG sendout stream and the overhead stream, such that the LNG sendout stream is heated and the overhead stream collected from the demethanizer is condensed.

[0009] In other words, the LNG regasification process comprises heat exchange between the lean LNG sendout stream and the overhead stream, to provide heating of the lean LNG sendout stream and cooling of the overhead stream, such that the overhead stream is condensed.

[0010] In this way, the lean LNG sendout stream is utilized to provide refrigeration for the overhead stream, which comprises the lean LNG product. Conversely, the heat energy from the overhead stream is utilized to heat the lean LNG sendout stream. This provides a more energy efficient system.

[0011] In some embodiments, heat exchanger may be used. For example, the heat exchanger may comprise multiple heat exchangers.

[0012] In some embodiments, a compressor compresses the overhead stream from the demethanizer upstream of the heat exchange process. In such embodiments, since the lean LNG sendout stream is utilized to provide refrigeration for the overhead stream, this enables the compressor to compress the overhead stream to an intermediate pressure (e.g. a lower pressure than may otherwise be possible). In other words, the lean LNG is compressed to an intermediate operating pressure. This intermediate operating pressure lowers the power requirement of the compressor, hence reducing the power demands of the process.

[0013] In some embodiments, utilizing the LNG sendout stream to provide refrigeration to the overhead stream results the lean LNG being condensed at a lower temperature with an intermediate pressure (e.g. a lower pressure than may otherwise be achieved).

[0014] In some embodiments, at least a portion of the lean LNG may be delivered from the collection chamber to the demethanizer as a reflux stream. The lean LNG having a lower temperature may result in lower lean LNG reflux requirement to the Demethanizer, improving the overall efficiency of the system.

[0015] In some embodiments, at least a portion of the lean LNG is delivered to a holding tank, e.g. from the collection chamber. The lean LNG having a lower temperature may result in a lower amount of flashed boil off gas (BOG) being sent to the holding tank.

[0016] In some embodiments, the lean LNG sendout stream is sent to a vaporizer, downstream of the heat exchange process, and then to the sendout pipeline. In such embodiments, since the sendout stream is heated via heat exchange, the heating requirement of the vaporizer is reduced, providing a more efficient process.

[0017] In some embodiments, the process disclosed herein comprises high temperature dense phase (i.e. high temperature and high pressure) sendout of the lean LNG. In other words, there is a single sendout stream sent to the sendout pipeline. This enhances the efficiency of the process.

[0018] In some embodiments, at least a portion of the lean LNG is delivered to a holding tank, e.g. from the collection chamber. Heat exchange between the lean LNG sendout stream and the overhead stream, to provide heating of the lean LNG sendout stream is beneficial when the lean LNG has been stored in a holding tank, for example, this enables the lean LNG to be stored at a lower temperature.

[0019] Optionally, wherein the heat exchange process further comprises heat exchange between the rich LNG feed stream, the lean LNG sendout stream and the overhead stream, such that the rich LNG feed stream is heated to an at least partially vaporized state for introduction into the demethanizer (e.g. a fully vaporized state), the LNG sendout stream is heated and the overhead stream collected from the demethanizer is condensed.

[0020] In this way, heat exchange is provided between the rich LNG feed stream, the lean LNG sendout stream and the overhead stream (comprising lean LNG), partially vaporizing the rich LNG feed stream, heating the lean LNG sendout stream, and condensing the overhead stream. This provides a more energy efficient system.

[0021] Optionally, wherein a portion of the rich LNG feed stream selectively bypasses the heat exchange process and is introduced directly to the demethanizer.

[0022] In this way, the amount of the rich LNG feed stream that is passed through the heat exchange process can be controlled, depending on whether the temperature of the rich LNG feed stream needs to be raised or lowered prior to introduction into the demethanizer. This enables control of the temperature at which rich LNG is fed into the demethanizer.

[0023] Optionally, the LNG regasification process further comprising separating an inlet LNG feed stream into a first rich LNG stream and a second rich LNG stream, wherein the rich LNG feed stream comprises the first rich LNG stream (i.e. the first rich stream is at least partially vaporized for introduction to the demethanizer); and introducing a first reflux flow in a liquid state into the demethanizer, the first reflux flow comprising the second rich LNG stream.

[0024] Utilizing the second rich LNG stream as a reflux stream provides for greater separation of methane from the ethane and heavier hydrocarbons in the demethanizer.

[0025] In some embodiments, a second reflux flow is introduced into the demethanizer, the second reflux flow comprising lean LNG from the collection chamber. In such embodiments, the use of the second rich LNG stream as a first reflux flow reduces the amount of lean LNG that is required as second reflux flow.

[0026] Optionally, wherein the first reflux flow is introduced into the demethanizer above the rich LNG feed stream (e.g. the first rich LNG stream).

[0027] Optionally, the LNG regasification process further comprising, in response to a change in composition of the LNG feed stream, adjusting a relative flow rate at which the first rich LNG stream and the first reflux flow are introduced into the demethanizer.

[0028] This enables LNG feed streams of varying compositions to be used in the process.

[0029] Optionally, the LNG regasification process further comprises introducing a second reflux flow in a liquid state into the demethanizer. In other words, a second reflux flow in a liquid state is flashed into the demethanizer.

[0030] Optionally, wherein the second reflux flow comprises at least a portion of the lean LNG from the collection chamber.

[0031] This provides for greater separation of methane from the ethane and heavier hydrocarbons in the demethanizer.

[0032] Optionally, wherein the second reflux flow is introduced into the demethanizer above the first reflux flow.

[0033] Optionally the amount of first and/or second reflux flow may be controlled. In this way, a wide range of rich LNG feed composition can be processed e.g. with ethane up to 20 mole percent in the rich LNG feed stream.

[0034] In some embodiments, the use of the second rich LNG stream as a first reflux flow in addition to a lean LNG stream as a second reflux flow provides for greater separation of methane from the ethane and heavier hydrocarbons in the demethanizer than would be provided by use of a lean LNG stream as reflux flow alone.

[0035] In some embodiments, the use of the demethanizer with first and second reflux flows may also provide for greater process efficiency and reduced power requirements, for example, the use of the second rich LNG stream as the first reflux flow may reduce the amount of lean LNG that is required as second reflux flow.

[0036] Optionally, the LNG regasification process,

further comprising collecting a bottom stream from the demethanizer, wherein the bottom stream from the demethanizer comprises a natural gas liquid (NGL) enriched in ethane and reduced in methane relative to the LNG feed stream, optionally wherein the LNG regasification process recovers at least 99 vol% of the ethane from the rich LNG feed stream in the bottom stream from the demethanizer.

[0037] Optionally, wherein the lean LNG sendout stream is sent to a vaporizer downstream of the heat exchange process, and then to the sendout pipeline.

[0038] In this way, the sendout stream is heated in the heat exchange process prior to treatment by the vaporizer. Consequently, the heating requirement of the vaporizer is reduced, providing a more efficient process. Furthermore, in some embodiments, pre-heating the LNG sendout stream results in the vaporizer having excess duty capacity, which potentially allows a higher sendout capacity e.g. when NGL is produced.

[0039] Optionally, the LNG regasification process, further comprising operating the LNG regasification process to:

a. to deliver a lean LNG sendout stream to a sendout pipeline, wherein the lean LNG sendout stream comprises at least a portion of the lean LNG; and/or
b. to deliver at least a portion of the lean LNG to a holding tank.

[0040] In other words, the lean LNG may be provided to the sendout pipeline and/or to a holding tank. In this way, greater flexibility in the distribution of the lean LNG is provided.

[0041] The lean LNG sendout rate can be flexible from a minimum to a peak sendout design capacity of vaporizer. In some embodiments, the minimum send out may be approximately 10% of the vaporizer design capacity. Furthermore, lean LNG produced can be stored in the holding tank, and LNG sendout may be at said minimum or higher, as required.

[0042] Even when the lean LNG sendout is at the minimum, NGL can still be collected from the bottom stream of the demethanizer, and the lean LNG produced stored in the holding tank. Accordingly, a flexible process is provided in which the LNG sendout rate can be varied, without impacting NGL production.

[0043] Optionally, wherein, when the LNG regasification process is operated to deliver lean LNG to the holding tank, the lean LNG is expanded in a liquid expander before delivery to the holding tank.

[0044] In this way, energy from the lean LNG can be recovered and converted into power, which can be used in any other part of the process. Accordingly, a more efficient process can be provided.

[0045] The liquid expander may also minimize the flash gas and boil off gas in the lean LNG holding tank by making the lean LNG colder with energy removal.

[0046] Optionally, at least a portion of the lean LNG is delivered to the sendout pipeline and at least a portion of the lean LNG is delivered to the holding tank.

[0047] In this way, flexibility in the process is enhanced and the supply of lean LNG to the sendout pipeline can be increased (i.e. by providing lean LNG to the sendout pipeline from both the collection chamber and the holding tank).

[0048] Optionally, wherein, when the LNG regasification process is operated to deliver a lean LNG sendout stream to a sendout pipeline, at least a portion of the lean LNG delivered to the sendout pipeline is first delivered to the holding tank and then subsequently delivered to the sendout pipeline after delivery to the holding tank, and another portion of the lean LNG is delivered to the sendout pipeline without first being delivered to the holding tank.

[0049] In this way, a peak sendout rate can be achieved by supplying lean LNG from both the collection tank and the holding tank. In some embodiments, the lean LNG sendout from the holding tank can be delivered to the sendout pipeline via the collection tank and/or bypassing the collection tank. Accordingly, flexibility in the process is enhanced.

[0050] Optionally, when operated in the first operating state, at least a portion of the lean LNG is delivered from the collection chamber and/or the holding tank to the sendout pipeline.

[0051] Optionally, the LNG regasification process further comprises operating the LNG regasification process in a second operating state in which at least a portion of the lean LNG is delivered to a holding tank.

[0052] Optionally, the LNG regasification process further comprises operating the LNG regasification process in a third operating state in which at least a portion of the lean LNG is delivered to the sendout pipeline and at least a portion of the lean LNG is delivered to the holding tank.

[0053] Optionally, the LNG regasification process further comprises operating the LNG regasification process in a fourth operating state in which at least a portion of the lean LNG is delivered to the sendout pipeline and at least a portion of the lean LNG is delivered to the holding tank, and wherein at least a portion of the lean LNG delivered to the holding tank is subsequently delivered to the sendout pipeline after delivery to the holding tank, and wherein at least a portion of the lean LNG delivered to the sendout pipeline is delivered to the sendout pipeline without first being delivered to the holding tank.

[0054] Optionally, wherein, in the second, third and/or fourth operating state, the lean LNG is expanded in a liquid expander before delivery to the holding tank.

[0055] Optionally, the LNG regasification process, further comprises operating the demethanizer in a first operating mode and operating the demethanizer in a second operating mode, wherein, in the second operating mode the demethanizer is operated at a higher pressure than in the first operating mode.

[0056] In some embodiments, the demethanizer may

be operated in the second (e.g. higher pressure) operating mode when there is excess fuel gas available for raising a temperature of the demethanizer bottoms. In some implementations operating in the second higher pressure operating mode may improve ethane and other heavier hydrocarbon recovery in the demethanizer. In some implementations operating in the second higher pressure operating mode may reduce compression power requirements of the overhead stream.

[0057] In an aspect of this disclosure a liquid natural gas (LNG) regasification process comprising a single column demethanizer process is provided, comprising:

a. introducing a rich LNG feed stream, comprising a mixture of at least methane and ethane, in an at least partially vaporized state into a demethanizer;
b. condensing an overhead stream from the demethanizer, wherein the overhead stream comprises a lean LNG enriched in methane and reduced in ethane relative to the rich LNG feed stream;
c. collecting the lean LNG in a collection chamber;
d. operating the LNG regasification process:

i. to deliver a lean LNG sendout stream to a sendout pipeline, wherein the lean LNG sendout stream comprises at least a portion of the lean LNG; and/or
ii. to deliver at least a portion of the lean LNG to a holding tank.

[0058] In a further aspect of this disclosure a liquid natural gas (LNG) regasification process comprising a single column demethanizer process is provided, comprising

a. introducing a rich LNG feed stream, comprising a mixture of at least methane and ethane, in an at least partially vaporized state into a demethanizer;
b. condensing an overhead stream from the demethanizer, wherein the overhead stream comprises a lean LNG enriched in methane and reduced in ethane relative to the rich LNG feed stream;
c. collecting the lean LNG in a collection chamber;
d. operating the LNG regasification process in a first operating state in which at least a portion of the lean LNG is delivered to a sendout pipeline; and
e. operating the LNG regasification process in a second operating state in which at least a portion of the lean LNG is delivered to a holding tank.

[0059] In other words, lean LNG originating from the overhead stream may be provided to the sendout pipeline and/or to a holding tank. In this way, greater flexibility in the distribution of lean LNG is provided.

[0060] Optionally, when operated in the first operating state, at least a portion of the lean LNG is delivered from the collection chamber and/or the holding tank to the sendout pipeline.

[0061] Optionally, the process comprises operating the LNG regasification process in a third operating state in which at least a portion of the lean LNG is delivered to the sendout pipeline and at least a portion of the lean LNG is delivered to the holding tank.

[0062] Optionally, the lean LNG may be delivered to the sendout pipeline from the collection chamber and/or from the holding tank.

[0063] Optionally, the lean LNG may be delivered to the collection chamber from the holding tank, prior to being delivered from the collection chamber to the sendout pipeline.

[0064] The lean LNG sendout rate can be flexible from a minimum to a peak sendout design capacity of the vaporizer. Furthermore, lean LNG produced can be stored in the holding tank, without any LNG sendout required.

[0065] Even when the lean LNG sendout is at the minimum, NGL can still be collected from the bottom stream of the demethanizer, and the lean LNG stored in the holding tank. Accordingly, a flexible process is provided in which the LNG sendout rate can be varied, without impacting NGL production.

[0066] Optionally, wherein, when the LNG regasification process is operated to deliver at least a portion of the lean LNG to the holding tank, the lean LNG is expanded in a liquid expander before delivery to the holding tank.

[0067] In this way, energy from the lean LNG can be recovered and converted into power, which can be used in any other part of the process. Accordingly, a more efficient process can be provided.

[0068] The liquid expander may also minimize the flash gas and boil off gas in the lean LNG holding tank.

[0069] Optionally, wherein, when the LNG regasification process is operated to deliver a lean LNG sendout stream to a sendout pipeline, the lean LNG delivered to the pipeline comprises:

a. lean LNG which has first been delivered to the holding tank and then subsequently delivered to the sendout pipeline after delivery to the holding tank, and/or
b. lean LNG delivered to the sendout pipeline without first being delivered to the holding tank.

[0070] In this way, a peak sendout rate can be achieved by supplying lean LNG from both the collection tank and the holding tank. In some embodiments, lean LNG sendout from the holding tank can be delivered to the sendout pipeline via the collection tank and/or bypassing the collection tank. Accordingly, flexibility in the process is enhanced.

[0071] In some embodiments, the process comprises operating the LNG regasification process in a fourth operating state in which at least a portion of the lean LNG is delivered to the sendout pipeline and at least a portion of the lean LNG is delivered to the holding tank, and wherein at least a portion of the lean LNG delivered to

the holding tank is subsequently delivered to the sendout pipeline after delivery to the holding tank, and wherein at least a portion of the lean LNG is delivered to the sendout pipeline is delivered to the sendout pipleline without first being delivered to the holding tank.

[0072] Optionally, when operated in the second, third and/or fourth operating state, the lean LNG is expanded in a liquid expander before delivery to the holding tank.

[0073] Optionally wherein the process comprises carrying out a heat exchange process comprising heat exchange between the lean LNG sendout stream and the overhead stream, such that the LNG sendout stream is heated and the overhead stream collected from the demethanizer is condensed.

[0074] Optionally, wherein a heat exchanger heats the LNG sendout stream and condenses the overhead stream collected from the demethanizer.

[0075] Optionally, wherein the heat exchanger heats the rich LNG feed stream using heat from the overhead stream collected from the demethanizer, such that the rich LNG feed stream is heated to an at least partially vaporized state for introduction into the demethanizer.

[0076] Optionally, a portion of the rich LNG feed stream selectively bypasses the heat exchange process and is introduced directly to the demethanizer.

[0077] Optionally, the process further comprises separating an inlet LNG feed stream into a first rich LNG stream and a second rich LNG stream, wherein the rich LNG feed stream comprises the first rich LNG stream (i.e. the first rich stream is at least partially vaporized for introduction to the demethanizer); and introducing a first reflux flow in a liquid state into the demethanizer, the first reflux flow comprising the second rich LNG stream.

[0078] Optionally, in response to a change in composition of the LNG feed stream, adjusting a relative flow rate at which the first rich LNG stream and the first reflux flow are introduced into the demethanizer.

[0079] Optionally, the process further comprises introducing a second reflux flow in a liquid state into the demethanizer, optionally wherein the second reflux flow comprises at least a portion of the lean LNG from the collection chamber.

[0080] Optionally, the process further comprises collecting a bottom stream from the demethanizer, wherein the bottom stream from the demethanizer comprises a natural gas liquid (NGL) enriched in ethane and reduced in methane relative to the LNG feed stream. Optionally, the LNG regasification process recovers at least 99 vol% of the ethane from the rich LNG feed stream in the bottom stream from the demethanizer.

[0081] Optionally, the lean LNG sendout stream is sent to a vaporizer downstream of the heat exchanger, and then to the sendout pipeline.

[0082] Optionally, the process comprises a single column demethanizer process.

[0083] Optionally, the process comprises operating the demethanizer in a first operating mode and operating the demethanizer in a second operating mode, wherein, in the second operating mode the demethanizer is operated at a higher pressure than in the first operating mode.

[0084] In a further aspect, a liquid natural gas (LNG) regasification system is provided, comprising a single column demethanizer process, comprising: a demethanizer arranged to receive at a first inlet of the demethanizer a rich LNG feed stream in an at least partially vaporized condition; the demethanizer operable to output at an overhead outlet an overhead stream comprising a lean LNG enriched in methane and reduced in ethane relative to the LNG feedstream; the demethanizer operable to output a bottom stream comprising natural gas liquid (NGL) enriched in ethane and reduced in methane relative to the LNG feed; and a collection chamber operable to receive the lean LNG, and a sendout fluid pathway downstream of the collection chamber and arranged to deliver a lean LNG sendout stream to a lean LNG sendout.

[0085] In an aspect of this disclosure a liquid natural gas (LNG) regasification system comprising a single column demethanizer system is provided, comprising: a demethanizer arranged to receive at a first inlet of the demethanizer a rich LNG feed stream in an at least partially vaporized condition; the demethanizer operable to output at an overhead outlet an overhead stream comprising a lean LNG enriched in methane and reduced in ethane relative to the LNG feedstream; the demethanizer operable to output a bottom stream comprising natural gas liquid (NGL) enriched in ethane and reduced in methane relative to the LNG feed; a collection chamber operable to receive the lean LNG; a sendout fluid pathway downstream of the collection chamber and arranged to deliver a lean LNG sendout stream to a lean LNG sendout; and a heat exchanger operable to carry heat exchange between the lean LNG sendout stream and the overhead stream, such that the LNG sendout stream is heated and the overhead stream output from the demethanizer is condensed.

[0086] Optionally, the demethanizer is arranged to receive a first rich LNG stream of a rich LNG stream in an at least partially vaporized state at the first inlet, and a first reflux flow comprising a second rich LNG stream of the rich LNG feed stream in a liquid condition at a second inlet.

[0087] Optionally, the system comprises a flow control apparatus arranged to adjust a relative flow rate at which the first rich LNG stream and the first reflux flow are introduced into the demethanizer.

[0088] Optionally, the demethanizer is arranged to receive, at a third inlet, a second reflux flow in a liquid condition. In other words, a second reflux flow in a liquid state is flashed into the demethanizer.

[0089] Optionally, wherein the heat exchanger is further operable carry out heat exchange between the rich LNG feed stream, the lean LNG sendout stream and the overhead stream, such that the rich LNG feed stream is heated to an at least partially vaporized state for introduction into the demethanizer, the lean LNG sendout

stream is heated and the overhead stream output from the demethanizer is condensed.

[0090] In other words, the heat exchanger is arranged to heat the rich LNG feed stream (e.g. the first rich LNG stream) using heat from the overhead stream output from the demethanizer, such that the rich LNG feed stream is heated to an at least partially vaporized state for introduction into the demethanizer.

[0091] Optionally, the system comprises a first feed pathway coupling the rich LNG feed inlet to the first inlet of the demethanizer via the heat exchanger.

[0092] Optionally, the system comprises a second feed pathway coupling the rich LNG feed inlet to the first inlet of the demethanizer bypassing the heat exchanger.

[0093] Optionally, wherein the system comprises at least one of:

a. a first fluid pathway fluidly coupling the lean LNG collection chamber to an inlet of the demethanizer,
b. a second fluid pathway fluidly coupling the lean LNG collection chamber to the lean LNG sendout,
c. a third fluid pathway fluidly coupling the lean LNG collection chamber to a holding tank,
d. a fourth fluid pathway fluidly coupling the holding tank to the lean LNG sendout,

wherein the second fluid pathway and/or the fourth fluid pathway comprises the sendout fluid pathway.

[0094] Optionally, wherein the system is operable to selectively flow the lean LNG from the lean LNG collection chamber along one or more of the first, second, third, and fourth fluid pathways, when present.

[0095] Optionally, the second and/or fourth fluid pathway comprises a vaporizer, downstream of the heat exchanger.

[0096] Optionally, the third fluid pathway comprises a liquid expander upstream of the holding tank.

[0097] In a further aspect, a liquid natural gas (LNG) regasification system comprising: a demethanizer arranged to receive at a first inlet of the demethanizer a rich LNG feed stream in an at least partially vaporized condition; the demethanizer operable to output at an overhead outlet an overhead stream comprising a lean LNG enriched in methane and reduced in ethane relative to the LNG feedstream; the demethanizer operable to output a bottom stream comprising natural gas liquid (NGL) enriched in ethane and reduced in methane relative to the LNG feed; and a collection chamber operable to receive the lean LNG; a sendout fluid pathway downstream of the collection chamber and arranged to deliver a lean LNG sendout stream to a lean LNG sendout; wherein the system comprises at least one of:

a. a first fluid pathway fluidly coupling the lean LNG collection chamber to an inlet of the demethanizer,
b. a second fluid pathway fluidly coupling the lean LNG collection chamber to the lean LNG sendout,
c. a third fluid pathway fluidly coupling the lean LNG collection chamber to a holding tank, and
d. a fourth fluid pathway fluidly coupling the holding tank to the lean LNG sendout.

[0098] It will be appreciated that the optional features described may apply to any aspect disclosed herein. All combinations contemplated are not recited explicitly for the sake of brevity.

Brief Description of Figures

[0099] Embodiments will now be described by way of example only with reference to the accompanying figures, in which:

FIG. 1 shows a schematic example of an LNG regasification system.
FIG. 2 shows an example of an LNG regasification process.
FIG. 3 shows an example of an LNG regasification process.

Detailed Description

[0100] As part of LNG regasification, it may be desirable to separate methane in the LNG from other components of the LNG. For instance, LNG arriving at an import terminal is typically composed primarily of methane (e.g. approximately 80-95 vol%) but also includes heavier hydrocarbons such as ethane, propane, and butane. This mixture of methane with heavier hydrocarbons may be characterized as "rich" LNG.

[0101] Aspects of this disclosure therefore include an LNG regasification process that separates rich LNG into a lean LNG and natural gas liquid (NGL). More particularly, in at least some embodiments, the LNG regasification process may use a single-column demethanizer to separate rich LNG into lean LNG and NGL.

[0102] As part of the disclosed regasification processes the ethane and other heavier hydrocarbons may be separated from the methane, resulting in at least two streams. For example, the regasification process may produce a first stream of "lean" LNG that is enriched in methane and reduced in ethane and other heavier hydrocarbons relative to the rich LNG and a second stream of natural gas liquid ("NGL") that is enriched in ethane and other heavier hydrocarbons and reduced in methane relative to the rich LNG. In examples, the lean LNG stream may be, for instance, at least 95 vol%, at least 97 vol%, or at least 99 vol% methane, and the NGL stream may be, for instance, less than 5 vol%, less than 3 vol%, or less than 1 vol% of methane.

Regasification System

[0103] FIG. 1 is a schematic illustration of an LNG regasification system 100. In the illustrated embodiment, the system 100 includes a demethanizer 138 that is

arranged to receive a first rich LNG stream 106 of an LNG feed stream 108 at a first inlet 104 of the demethanizer 138.

[0104] The demethanizer 138 is arranged to receive a first reflux flow of a second rich LNG stream 112 of the LNG feed stream 108 at a second inlet 110 of the demethanizer 138. The demethanizer 138 is also arranged to receive a second reflux flow of lean LNG stream 210 at a third inlet 212 of the demethanizer.

[0105] The demethanizer 138 receives the first rich LNG stream 106 in an at least partially vaporized state and the two reflux flows in liquid states are flashed into the demethanizer. In some implementations a partially vaporized state may be present when the vapor fraction of the stream is greater than 0% and the stream is heated above the saturation condition and less than 100% (which would be fully vaporized). It will be understood by those skilled in the art that the saturation condition occurs when there is 0% vapor present (i.e. the stream is in an entirely liquid state). It will be appreciated that, in some embodiments, the first rich LNG stream may be heated to a substantially fully vaporized state (i.e. the stream is substantially entirely vapor).

[0106] The demethanizer 138 is operable to output at an overhead outlet 116 an overhead stream 136 enriched in methane and reduced in ethane relative to the LNG feed stream 108.

[0107] The demethanizer 138 in this embodiment is operable to output at a bottom outlet 120 a bottom stream 158 enriched in ethane and reduced in methane relative to the LNG feed stream 108. The use of the demethanizer 138 with first 112 and second 210 reflux flows in this example may provide for enhanced recovery of ethane and other heavier hydrocarbons from the LNG feed stream 108.

[0108] In some implementations, the use of the second rich LNG stream 112 of the LNG feed stream 108 as a first reflux flow in addition to a second lean LNG stream 208 as reflux flow provides for greater separation of methane from the ethane and heavier hydrocarbons in the demethanizer 138 than would be provided by use of a single lean LNG stream as reflux flow alone.

[0109] In some implementations, the use of the demethanizer 138 with first and second reflux flows may also provide for greater process efficiency and reduced power requirements, with the use of the second rich LNG stream 112 as the first reflux flow reducing the amount of lean LNG (discussed further below) that is required as the second reflux flow.

LNG Feed Stream

[0110] In the embodiment of FIG. 1, the LNG feed stream 108 enters the system at an inlet 124. The LNG feed stream 108 entering the system at inlet 124 may be termed an "inlet LNG feed stream". The LNG feed stream 108 may be a rich LNG feed stream composed primarily of methane (e.g. approximately 80-95 vol% methane) but also including heavier hydrocarbons such as ethane (e.g. approximately 2-12 vol% ethane), propane (e.g. approximately 1-4 vol% propane), and butane and heavier hydrocarbons (e.g. approximately 0-1 vol% butane and heavier hydrocarbons in total). The LNG feed stream 108 may also include nitrogen in small amounts (e.g. 0-3 vol% nitrogen). The composition and relative percentages of the components of the LNG feed stream 108 may vary based or region in which the LNG originated, based on how the LNG was collected, and/or based on how the LNG was processed prior to being received in the LNG regasification system. The LNG feed stream 108 may be a mixture of at least methane and ethane.

[0111] The LNG feed stream 108 may come directly from an LNG carrier (e.g. a shipping vessel) arriving at an import facility, from temporary storage tanks at the import facility, or may be delivered to the regasification system in other manners. The LNG feed stream 108 may be in a liquid state.

[0112] The LNG feed stream 108 is fed from the inlet 124 to a pump 126. From the pump 126, the LNG feed stream 108 is separated into a first rich LNG stream 101 and a second rich LNG stream 112. In some implementations most of the LNG feed stream 108 is directed into the first rich LNG stream 101 with the remainder of the LNG feed stream 108 directed into the second rich LNG stream 112 (e.g. at least 60 vol%, at least 70 vol%, at least 80 vol%, at least 90 vol%, or at least 95 vol% of the LNG feed stream 108 is directed into the first rich LNG stream 101).

[0113] In the embodiment shown in FIG. 1, the relative amount of flow directed into the first and second rich LNG streams 101, 112 from the LNG feed stream 108 may be varied by flow control valves 125, 128. As discussed in further detail below, in some implementations, the relative flow rates of the first and second LNG steams 101, 112 may be adjusted in response to a change in composition of the LNG feed stream 108.

[0114] In the embodiment of FIG. 1, after being separated into the first and second rich LNG streams 101, 112, the first rich LNG stream 101 is heated to an at least partially vaporized state. The first rich LNG stream 101 passes from the pump 126 to a heat exchanger 130. The first rich LNG stream 101 is heated to an at least partially vaporized state by the heat exchanger 130.

[0115] The heat exchanger 130 is arranged to receive the first rich LNG stream 101, and also arranged to receive a lean LNG sendout stream 188 (discussed further below) and an overhead stream 134 from the demethanizer 138 (also discussed further below). The heat exchanger 130 is operable to exchange heat from the overhead stream 134 to the first rich LNG stream 101 and to the LNG sendout stream 188. The heat exchanger 130 condenses the overhead stream 134, heats the LNG sendout stream 188, and at least partially vaporizes the first rich LNG stream 101.

[0116] The heat exchanger 130 may be a brazed aluminum type heat exchanger, a shell and tube heat ex-

changer, or another type of heat exchanger. The heat exchanger 130 may be a single unit or a functional assembly of several heat exchangers.

[0117] Downstream of the heat exchanger 130, the first rich LNG stream 106 is introduced in the at least partially vaporized state into demethanizer 138 at the first inlet 104. The fluid path from the inlet 124, to the demethanizer 138, via the heat exchanger 130, can be thought of as a first feed pathway.

[0118] In the embodiment shown in FIG. 1 the temperature at which the first rich LNG stream 106 is introduced into the demethanizer 138 is controlled by a bypass valve 142, which regulates the flow rate of a bypass stream 144, which is part of the first rich LNG stream 106 that bypasses heat exchanger 130. A temperature controller 146 monitors the temperature of the first rich LNG stream 106 prior to introduction into demethanizer 138 and controls the bypass valve 142 such that less or more of the first rich LNG stream 106 passes through the bypass stream 144 instead of the heat exchanger 130 prior to introduction into the demethanizer 138, depending on whether the temperature of the first rich LNG stream 106 needs to be raised or lowered prior to introduction into the demethanizer 138.

[0119] For instance, if the temperature of the first rich LNG stream 106 monitored at the temperature controller 146 is above a desired temperature for the first rich LNG stream 106 to be introduced into the demethanizer 138, the temperature controller 146 may open or further open the bypass valve 142 to increase the flow rate of the first rich LNG stream 106 that bypasses the heat exchanger 130 via the bypass stream 144. Conversely, if the temperature of the first rich LNG stream 106 monitored at the temperature controller 146 is below a desired temperature for the first rich LNG stream 106 to be introduced into the demethanizer, the temperature controller 146 may close (partially or entirely) the bypass valve 142 to decrease the flow rate of the first rich LNG stream 106 that bypasses the heat exchanger 130 via bypass stream 144.

[0120] The fluid path from the inlet 124, to the demethanizer 138, bypassing the heat exchanger 130, can be thought of as a second feed pathway.

Demethanizer

[0121] The demethanizer 138 in FIG. 1 is arranged to receive the first rich LNG stream 106 and to output a bottom stream 158 and an overhead stream 136. The bottom stream 158 from the demethanizer 138 is a natural gas liquid (NGL) enriched in ethane (and other heavier hydrocarbons) and reduced in methane relative to the first rich LNG stream 106. The overhead stream 136 from the demethanizer 138 is enriched in methane and reduced in ethane (and other heavier hydrocarbons) relative to the first rich LNG stream 106.

[0122] In some implementations the first rich LNG stream 106 is introduced into the demethanizer 138 at a temperature above the vaporization temperature of the LNG stream 106 (e.g. above approximately -256° F).

[0123] The second rich LNG stream 112 is introduced as a first reflux flow in a liquid condition into the demethanizer 138 at the second inlet 110. The first reflux flow is introduced into the demethanizer 138 above the first rich LNG stream 106. In the illustrated embodiment, the first reflux flow is a mid-reflux for lower sections of the demethanizer 138.

[0124] The second reflux flow is introduced in a liquid condition into the demethanizer 138 at the third inlet 212. The second reflux flow of lean LNG is introduced into the demethanizer 138 above the first reflux flow. The second reflux flow may be a recycled portion of the overhead stream 134 of the demethanizer 138. The first and second reflux flows increase absorption and separation of ethane and heavier hydrocarbons in the demethanizer 138, thus increasing the ethane and heavier hydrocarbon concentration in the demethanizer bottom stream 158 and increasing the methane concentration in demethanizer overhead stream 136.

[0125] In at least some embodiments, in response to a change in composition of the LNG feed stream 108, the flow rates at which the first rich LNG stream 106 and the first reflux flow (second rich LNG stream 112) are introduced into the demethanizer 138 may be adjusted. In the embodiment of FIG. 1, the flow control valve 128 allows adjusting of the flow rate at which the first rich LNG stream 106 is introduced into the demethanizer 138. The flow control valve 125 allows adjusting of the flow rate at which the first reflux flow (via second rich LNG stream 112) is introduced into the demethanizer 138. The adjustments may be made automatically or manually and may be made in response to a determination that the composition of the LNG feed stream 108 has changed (e.g. as determined by a system operator based on either specific measurements of the LNG feed stream 108 or based on knowledge of the source of the LNG feed stream 108). In some embodiments, the composition of the LNG feed stream 108 may change from a relatively lean LNG feed stream to a relatively rich LNG feed stream (i.e. the percentage of ethane and other heavier hydrocarbons relative to methane in the LNG feed stream may go up). In such an embodiment, increasing the flow rate of the first reflux flow (via the second rich LNG stream 112) may provide additional liquid acting as reflux flows, which increases the absorption capacity in the demethanizer 138 to capture the higher percentage of heavier hydrocarbons into the bottom stream 158.

[0126] In some embodiments, the composition of the LNG feed stream 108 may change from a relatively rich LNG feed stream to a relatively lean LNG feed stream (i.e. the percentage of methane relative to ethane and other heavier hydrocarbons in the LNG feed stream may go up). In such an embodiment, less reflux flow in the demethanizer 138 may be necessary to effectively separate out the ethane and heavier hydrocarbons into the bottom stream 158, and thus the flow rate of the first reflux

flow (via the second rich LNG stream 112) may be decreased accordingly.

[0127] An overhead stream 136 is collected from the demethanizer 138, which is a lean LNG enriched in methane and reduced in ethane relative to the LNG feed stream 108. As noted above and discussed in further detail below, the lean LNG from the overhead stream 136 may be used as the second reflux flow introduced into the demethanizer 138 at the third inlet 212.

[0128] A second portion of the lean LNG product stream 206 is flow controlled with a control valve 214. The flow control valve 214 allows adjusting of the flow rate at which the second reflux flow (via second portion of the lean LNG product stream) is introduced into the demethanizer 138. The second reflux stream is optionally cooled by a cooler 216, then feeds into the demethanizer as top reflux. In this way, the flowrate of the second reflux flow can be adjusted such that the system is configured to recover a target amount of ethane (and other heavier hydrocarbon recovery) from the rich LNG feed stream, e.g. recovery of at least 97 vol%, at least 98 vol%, or at least 99 vol% of the ethane and other heavier hydrocarbons from the rich LNG feed stream 108 into the bottom stream 158 from the demethanizer 138.

[0129] In some implementations the demethanizer 138 may operate at a pressure in the range of from 220 to 560 psia, or 245 to 535 psia, or 270 to 510 psia as measured at an upper portion of the demethanizer 138. The demethanizer 138 may operate at a temperature in the range of from -100 to -205° F, or -115 to -190° F, or -130 to -175° F as measured at an upper portion of the demethanizer 138. The demethanizer 138 may operate at a temperature in the range of from -12 to +95° F, or +3 to +80° F, or +18 to +65° F as measured at a lower portion of the demethanizer 138.

[0130] In the embodiment shown in FIG. 1, the temperature of the demethanizer 138 is regulated using a side reboiler 152 and a bottom reboiler 154. The reboilers 152, 154 may use heat sources that are typically available at LNG terminals, which typically provide operating temperatures greater than +70° F. The reboilers 152, 154 may alternatively use other heat sources. The heating media used by the reboilers 152, 154 may be a mixture of ethylene glycol and water, propylene glycol and water, hot oil or other combinations of heating fluids commercially available. The side reboiler 152 allows for reduced duty cycles in the bottom reboiler 154.

[0131] In some embodiments, the Demethanizer reboilers 152, 154 are set to remove methane in the NGL product at a target of <1.45 mol% Methane in the NGL product.

[0132] In some implementations the demethanizer 138 may be operated in multiple operating modes. For instance, the demethanizer 138 may be operated in a first operating mode and a second operating mode, with the demethanizer 138 operated at a higher pressure in the second operating mode than in the first operating mode. For instance, when operated in the first operating mode, the demethanizer 138 may be operated at a pressure up to and including 350 psia (or up to and including 325 psia, or up to and including 300 psia, or up to and including 270psia) as measured at an upper portion of the demethanizer 138, and when operated in the second operating mode, the demethanizer 138 may be operated at a pressure up to and including 560psia (or up to and including 535psia, or up to and including 510psia) as measured at an upper portion of the demethanizer 138. The second operating mode facilitates improved recovery and reduces the compressor 156 power requirement.

[0133] In some instances, the demethanizer 138 may be operated in the first lower pressure operating mode when there is a low heat level available for the reboilers 152, 154 and may be operated in the second higher pressure operating mode when there is excess fuel gas available for heating of the reboiler 152, 154 medium. In some implementations operating in the second higher pressure operating mode may improve ethane and other heavier hydrocarbon recovery in the demethanizer 138 and may also reduce compression power requirements (e.g. compression power requirements at the demethanizer overhead compressor 156).

[0134] In some embodiments, the Demethanizer operating pressure is dependent on the inlet gas composition and/or the heating medium available.

[0135] In the embodiment of FIG. 1 an overhead stream 136 is collected from the demethanizer 138 that is enriched in methane and reduced in ethane and other heavier hydrocarbons relative to the first rich LNG stream 106. A compressor 156 compresses the overhead stream 136 from the demethanizer 138 to form a compressed stream 134. In some implementations the compressor 156 compresses the overhead stream 136 to a pressure in the range of from 350 to 600 psia. In the embodiment of FIG. 1 the compressor 156 is controlled by a pressure controller 166. The compressor discharge pressure may be dependent on the inlet gas composition, the ethane (and heavier hydrocarbon) recover rate, and/or the sendout rate.

[0136] In the embodiment of FIG. 1 a bottom stream 158 is collected from the demethanizer 138. The bottom stream 158 is a natural gas liquid (NGL) that is enriched in ethane and other heavier hydrocarbons and reduced in methane relative to the LNG feed stream 108 and relative to the first rich LNG stream 106. In at least some implementations, the LNG regasification system 100 described herein recovers at least 97 vol%, at least 98 vol%, or at least 99 vol% of the ethane and other heavier hydrocarbons from the LNG feed stream 108 into the bottom stream 158 from the demethanizer 138.

[0137] FIG. 1 illustrates two options for sendout of NGL product from the bottom stream 158 from the demethanizer 138. One of the options shown in FIG. 1 is that a pump 160 can pump the NGL in the bottom stream 158 from the demethanizer 138 to an NGL terminal 162 for delivery as NGL product. The other option shown in FIG. 1 involves delivery of NGL in the bottom stream 158 to a

de-ethanizer 164 and using an ethane delivery pump 228 and a heavier hydrocarbon delivery pump 230 to deliver ethane product to an ethane terminal 232 and a heavier hydrocarbon to product terminal 234 respectively. Either option (162 or 232 / 234) may be selected depending on demand for a particular type of NGL product. In other implementations, a system may include only one of these options or may include other functionality for sendout of NGL product.

Lean LNG

[0138] In the embodiment of FIG. 1 lean LNG is collected in the overhead stream 136 from the demethanizer 138 and compressed by the compressor 156 to a compressed overhead stream 134. The lean LNG is then passed through the heat exchanger 130 and condensed. A lean LNG collection chamber 168 is arranged to receive the lean LNG of the overhead stream 134. The subcooled condensed lean LNG 242 feeds into the lean LNG collection chamber 168 at inlet 170. In some implementations the lean LNG collection chamber 168 may be a surge drum. In other implementations the lean LNG collection chamber 168 may be another type of holding chamber configured to temporarily hold lean LNG.

[0139] The lean LNG collection chamber 168 may operate in a pressure in the range of from 350 to 600 psia and a temperature in the range of from -180 to -260° F In the embodiment shown in FIG. 1, the lean LNG collection chamber 168 includes a vapor vent 246 as Normal No Flow (NNF). The vapor vent 246 in this embodiment is a pressure controlled valve. In some implementations, when vapor is present, vapor vent 246 facilitates subcooling stream 242.

[0140] In the system of FIG. 1, several fluid pathways fluidly couple the lean LNG collection chamber 168 to other components of the system such that the system is operable to selectively flow the lean LNG from the lean LNG collection chamber 168 along one or more of those fluid pathways to various destinations.

[0141] A first fluid pathway includes fluid pathway segments indicated by reference numerals 172, 190, 208, 210 in FIG. 1 and fluidly couples the lean LNG collection chamber 168 to the third inlet 212 of the demethanizer 138 such that the lean LNG can be recycled as the second reflux flow into the demethanizer 138. In the illustrated embodiment, the first fluid pathway also includes a feed cooler 216 at which lean LNG is optionally cooled before being fed to the demethanizer 138. In some embodiments, the feed cooler 216 may be omitted.

[0142] A second fluid pathway includes fluid pathway segments indicated by reference numerals 172, 174, 186, 188 and fluidly couples the lean LNG collection chamber 168 to a vaporizer 182 and a lean LNG sendout 184 for sending a lean LNG sendout stream 188 to a pipeline using a sendout pump 226.

[0143] A third fluid pathway includes fluid pathway segments indicated by reference numerals 172, 190, 192, 194, 196 and fluidly couples the lean LNG collection chamber 168 to a liquid expander 198 and a holding tank 200, with an optional send out of a portion of the stream 194 to a regasification unit as a stream indicated by reference numeral 224.

[0144] A fourth fluid pathway includes the fluid pathway segment indicated by reference numerals 202 and fluidly couples the holding tank 200 to the vaporizer 182 and the lean LNG sendout 184, either by recycling the lean LNG from the holding tank 200 back to the lean LNG collection chamber 168 and then to the vaporizer 182 and lean LNG sendout 184 via the second fluid pathway including fluid pathway segments indicated by reference numerals 172, 174, 186, 188, or by bypassing the lean LNG collection chamber 168 via a bypass segment 204 and then via part of the second fluid pathway including fluid pathway segments indicated by reference numerals 186 and 188.

[0145] The fluid pathway segments indicated by reference numerals 186 and 188 may be thought of as a "sendout fluid pathway", which is downstream of the collection chamber 168 and arranged to deliver a lean LNG sendout stream to the lean LNG sendout 184. In the embodiment of FIG. 1, the second fluid pathway and the fourth fluid pathway both comprise the "sendout fluid pathway".

[0146] The LNG regasification system 100 illustrated in FIG. 1 is configured to operate in several different operating states in which some of these fluid pathways are open and permit flow of lean LNG to various components of the system and other fluid pathways are closed and prevent flow of lean LNG from the collection chamber 168 along those pathways. Although not shown in FIG. 1, the LNG regasification system 100 may include control valves, additional pumps not shown in FIG. 1, or other functionality facilitating opening and closing of the fluid pathways from the collection chamber 168.

[0147] In a first operating state of the LNG regasification system 100, the lean LNG is delivered to a sendout pipeline. In such a first operating state the second fluid pathway (including fluid pathway segments 172, 174, 186, 188) fluidly couples the lean LNG collection chamber 168 to the vaporizer 182 and the lean LNG sendout 184 for sending a lean LNG sendout stream 188 to the sendout pipeline. Additionally or alternatively, in the first operating state, the fourth fluid pathway (including fluid pathway segments 202,204) fluidly couples the holding tank 200 and the lean LNG sendout 184. The system in FIG. 1 allows for LNG sendout via lean LNG sendout stream 188 of a minimum of 10% of the vaporizer design capacity to 100% of the vaporizer design capacity.

[0148] In a second operating state of the LNG regasification system 100, the lean LNG is delivered to the holding tank 200. In such a second operating state the third fluid pathway (including fluid pathway segments 172, 190, 192, 194, 196) fluidly couples the lean LNG collection chamber 168 to the liquid expander 198 and the holding tank 200.

[0149] In the embodiment of FIG. 1 a pressure con-

troller and adjusting valve assembly 218 manages the discharge pressure of the liquid expander 198 to maintain the expander outlet at a subcooled state. In the embodiment of FIG. 1 the holding tank 200 generates boil off gas 220 and remaining in-tank lean LNG 244 which accumulates until send out is required.

[0150] When additional send out capacity is needed, the lean in-tank LNG 244 may be subsequently delivered back out of the holding tank 200 along the pathway segment indicated by reference numeral 202 to the collection chamber 168 by an in-tank pump 222, or may bypass the collection chamber 168 via the pathway segment indicated by reference numeral 204 for delivery to the lean LNG sendout 184.

[0151] It will be appreciated that 0-100% of the lean LNG collected in the collection chamber 168, less the amount diverted as the second reflux flow to the demethanizer 138, can be sent to the holding tank 200. Given that the regasification system 100 is operated to sendout a minimum of 10% of the vaporizer design capacity to the pipeline, in circumstances where 100% of lean LNG collected in the collection chamber 168 is sent to the holding tank 200, the flow required for the 10% minimum sendout must be sent from the holding tank 200 to the LNG sendout 184 using the in-tank pump 222.

[0152] In circumstances where less than 100% of lean LNG collected in the collection chamber 168 is sent to the holding tank 200, the flow required for the 10% minimum sendout can be sent from the collection chamber 168 and/or the holding tank 200 to the LNG sendout 184.

[0153] In circumstances where there is a demand for "peak" sendout of lean LNG to the LNG sendout 184 (i.e. corresponding to the peak of the vaporizer design capacity), lean LNG can be sent from both the holding tank 200 and the collection chamber 168. Accordingly, it will be appreciated that the "peak" sendout rate can be higher than 100% of the rate at which lean LNG is collected in the collection chamber 168 from the overhead stream, less the amount diverted as the second reflux flow to the demethanizer 138. In other words, the peak sendout of lean LNG to the LNG sendout 184 can be higher than 100% of the rate of production of lean LNG by the demethanizer 138 (less the amount diverted as the second reflux flow to the demethanizer 138). In such embodiments, the bypass fluid segment 204 enables additional lean LNG to be sent to the LNG sendout 184, in addition to the lean LNG sent out directly from the collection chamber 168, such that sufficient lean LNG is provided to the LNG sendout 184 (i.e. the pump 226, heat exchanger 130 and vaporizer 182) to meet the "peak" demand.

[0154] Accordingly, in such embodiments, it will be appreciated that the "peak" sendout of lean LNG to the LNG sendout 184 is not the same as the rate of production of lean LNG from the demethanizer 138 (e.g. less the amount diverted as the second reflux flow to the demethanizer 138). In fact, the "peak" sendout of lean LNG is higher than the rate of production of lean LNG from the demethanizer 138 (e.g. less the amount diverted as the second reflux flow to the demethanizer 138).

[0155] As another alternative, instead of being delivered to the holding tank 200, lean LNG may be directed from liquid expander 198 to an LNG regasification terminal 224.

[0156] In a third operating state of the LNG regasification system 100, the lean LNG is delivered to both the sendout pipeline 184 (via a fluid pathway including the fluid pathway segments indicated by reference numerals 172, 174, 186, 188) and the holding tank 200 (via the fluid pathway segments indicated by reference numerals 172, 190, 192, 194, 196).

[0157] In a fourth operating state of the LNG regasification system 100, the lean LNG is delivered to both the sendout pipeline 184 (via fluid pathway including the fluid pathway segments indicated by reference numerals 172, 174, 186, 188) and the holding tank 200 (via the fluid pathway segments indicated by reference numerals 172, 190, 192, 194, 196), and at least a portion of the lean LNG delivered to the holding tank 200 is subsequently delivered to the sendout pipeline 184 after delivery to the holding tank 200. The portion of the lean LNG delivered to the holding tank 200 that is subsequently delivered to the sendout pipeline 184 may flow via the fluid pathway segment indicated by reference numeral 202 back to the collection chamber 168 and then to the sendout pipeline 184 via segments indicated by reference numerals 172, 174, 186, 188, or may bypass returning to the collection chamber 168 by flowing via the segments indicated by reference numerals 202, 204, and then via the segments indicated by reference numerals 186, 188 to the sendout pipeline 184.

[0158] In the embodiment of FIG. 1, the multiple operating states at which the system can be operated allows for flexibility in the lean LNG minimum to peak sendout rate, from 10% to 100% of the design capacity of the vaporizer 182.

[0159] In any and all of the first, second, third, and fourth operating states described above the system may continue to recycle part of the lean LNG from the collection chamber 168 to the third inlet 212 of the demethanizer 138 as the second reflux flow via fluid pathway segments indicated by reference numerals 172, 190, 208, 210. The reflux flow in the demethanizer 138 facilitates increasing ethane and other heavier hydrocarbon concentrations in demethanizer bottom stream 158 and increasing methane concentration in demethanizer overhead stream 136. The reflux flow into the demethanizer 138 in the FIG. 1 embodiment may optionally be cooled by cooler 216. In other implementations cooler 216 is unnecessary and heat exchanger 130, side reboiler 152, and bottom reboiler 154 may provide adequate temperature conditions in the demethanizer 138.

Example LNG Regasification Process

[0160] FIG. 2 shows an example of an LNG regasifica-

tion process. The LNG regasification process can be performed using the LNG regasification system shown in FIG. 1 or may be performed with a different LNG regasification system. Similarly, while the LNG regasification system of FIG. 1 may be used to perform the LNG regasification process of FIG. 2, the LNG regasification system of FIG. 1 may also or alternatively be used to perform different LNG regasification processes.

[0161] In the LNG regasification process of FIG. 2, at step 250, an LNG feed stream is heated to an at least partially vaporized condition. The LNG feed stream is a mixture of at least methane and ethane. When the system of FIG. 1 is used, LNG feed stream from inlet 124 is separated into a first rich LNG stream 101 and a second rich LNG stream 112, and the first rich LNG stream is heated to an at least partially vaporized state.

[0162] When the system of FIG. 1 is used for the process of FIG. 2, a heat exchanger 130 is used to heat the first rich LNG stream 101 to the at least partially vaporized condition.

[0163] In some embodiments, as discussed above, a portion of the rich LNG feed stream (e.g. the first rich LNG stream) selectively bypasses the heat changer 130 and is introduced directly to the demethanizer.

[0164] At step 252, the rich LNG stream is introduced to the demethanizer 138 at the first inlet 104. The rich LNG stream is introduced in the at least partially vaporized condition. When the system of FIG. 1 is used for the process of FIG. 2, the first rich LNG stream, a first reflux flow, and a second reflux as lean LNG stream flow are introduced into the demethanizer 138. The first rich LNG stream is introduced in the at least partially vaporized condition, while the first and second reflux flows are introduced in liquid conditions (i.e. are flashed) into the demethanizer 138. The first reflux flow is the second rich LNG stream that was separated from the LNG feed stream. The first reflux flow may be introduced into the demethanizer above the first rich LNG stream, and the second reflux flow may be introduced into the demethanizer 138 above the first reflux flow. The second reflux flow is lean LNG.

[0165] A relative flow rate at which the first rich LNG stream and the first reflux flow are introduced into the demethanizer 138 may be adjusted in response to a change in composition of the LNG feed. When the system of FIG. 1 is used, the first rich LNG stream 106 is introduced into the demethanizer 138 at inlet 104, the first reflux flow (the second rich LNG stream 112) is introduced into the demethanizer 138 at inlet 110, and the second reflux flow is introduced into the demethanizer at inlet 212, with flow control valves 125, 128 facilitating adjustment of relative flow rates of the first rich LNG stream and the first reflux flow.

[0166] The demethanizer 138 may be operated in a first operating mode and operated in a second operating mode, with the second operating mode the demethanizer operating at a higher pressure than the first operating mode. As one example, in the first operating mode the demethanizer is operated at a pressure up to 270 psia and in the second operating mode the demethanizer is operated at a pressure up to 510 psia. When the system of FIG. 1 is used, the operation of reboilers 152, 154 may be adjusted to change the operating mode of the demethanizer 138 between lower and higher pressure modes.

[0167] At step 254, a bottom stream is collected from the demethanizer. The bottom stream from the demethanizer is an NGL enriched in ethane and reduced in methane relative to the LNG feed stream. In at least some implementations of the process shown in FIG. 2, the LNG regasification process recovers at least 99 vol% (or at least 97 vol% or at least 98 vol%) of the ethane (and any heavier hydrocarbons) from the LNG feed stream in the bottom stream from the demethanizer. When the system of FIG. 1 is used, the bottom stream 158 from demethanizer 138 is collected and may be delivered to NGL terminal 162 or to de-ethanizer 164.

[0168] At step 256, an overhead stream is collected from the demethanizer. The overhead stream is a lean LNG enriched in methane and reduced in ethane relative to the LNG feed stream. When the system of FIG. 1 is used, the overhead stream 136 is collected from the demethanizer 138 and compressed by compressor 156 to form the stream indicated by reference numeral 134.

[0169] At step 258, the overhead stream 134 is condensed by heat exchanger 130 and collected in collection chamber 168.

[0170] As discussed above, depending on the operating state of the LNG regasification system / process, the lean LNG collected in the overhead stream may be recycled and/or delivered to various destinations.

[0171] At step 260, prior to sendout, a lean sendout stream 186, comprising the lean LNG, is heated by the heat exchanger 130.

[0172] At step 262, the heated lean LNG sendout stream is vaporized in vaporizer 182 then delivered to a sendout pipeline.

[0173] FIG. 3 shows a further example of an LNG regasification process, illustrating how the lean LNG collected in the overhead stream may be recycled and/or delivered. Following step 258 (as shown in FIG. 2), the LNG regasification process may be operated to deliver a lean LNG sendout stream to a sendout pipeline 262, wherein the lean LNG sendout stream comprises lean LNG; and/or to deliver lean LNG to a holding tank 264.

[0174] When the system of FIG. 1 is used, the lean LNG is expanded in the liquid expander 198 prior to delivery to the holding tank 200.

[0175] In some embodiment, delivering the lean LNG to the sendout pipeline 262 includes delivering lean LNG which has first been delivered to the holding tank and then subsequently delivered to the sendout pipeline after delivery to the holding tank, and/or lean LNG delivered to the sendout pipeline without first being delivered to the holding tank.

Performance

[0176] The embodiment of an LNG regasification system and process shown in FIGS. 1, 2 and 3 and described above provide an efficient and flexible system and process for regasification of LNG and recovery of ethane and heavier hydrocarbons.

[0177] The use of a demethanizer with dual reflux streams provides for high levels of ethane recovery (e.g. at least 97+ vol%, at least 98+ vol%, or at least 99+ vol%). When lean LNG product is sent out directly to the pipeline via the lean LNG sendout 184, the heat exchanger 130 is used to recover refrigeration from the lean LNG stream 188 that is used to condense the lean LNG overhead stream 134 from the demethanizer 138. When the lean LNG product is sent to the holding tank 200, the liquid expander 198 is used to recover energy from the lean LNG product and to minimize flash gas / boil off gas in the holding tank 200. At times of peak lean LNG product demand, the in-tank pump 222 of holding tank 200 can be operated to send out the lean LNG product 244 to supplement lean LNG product from the collection chamber 168 for send out via pump 226.

[0178] The use of demethanizer 138 with multiple reflux streams, the use of the liquid expander 198 to recover power from the lean LNG product prior to delivery to holding tank 200, and the use of the heat exchanger 130 to recover refrigeration from the lean LNG product prior to sendout at the lean LNG sendout 184 all provide for increased process efficiency with reduced power consumption. The use of heat exchanger 130 to recover refrigeration from the lean LNG product prior to sendout at the lean LNG sendout 184 as preheating also reduces the duty required of the vaporizer 182, further increasing the sendout vaporizer 182 capacity. Without such preheating, the vaporizer would be required to do both preheating and vaporization.

[0179] The adjustability of the rates at which first rich LNG stream 106 and second rich LNG stream 112 are delivered to the demethanizer 138 allows for efficient and effective processing of a wide range of rich LNG feed compositions.

[0180] The multiple operating states at which the system 100 can be operated allows for flexibility in the lean LNG sendout rate, from 10% to 100% of the design capacity of the vaporizer 182. When necessary, peak sendout can be supplied from holding tank 200 in addition to direct sendout from collection chamber 168.

[0181] When high temperature heat is available for the demethanizer 138 reboilers 152, 154, the demethanizer 138 may be operated at pressures up to and including 560psia (or up to and including 535psia, or up to and including 510psia), which improves recovery and reduces the demethanizer 138 overhead compressor power requirements.

[0182] The embodiments disclosed herein are included for demonstration purposes only and not as limitations on the scope of the invention. Other variations in the construction, configuration, and performance of the LNG regasification systems and processes may be made without departing from the scope or spirit of the inventions set out in the following claims, and those of skill in the art will recognize that the foregoing descriptions were provided by way of example only.

Claims

1. A liquid natural gas (LNG) regasification process comprising a single column demethanizer process, the process comprising:

   a. introducing a rich LNG feed stream, comprising a mixture of at least methane and ethane, in an at least partially vaporized state into a demethanizer;
   b. condensing an overhead stream from the demethanizer, wherein the overhead stream comprises a lean LNG enriched in methane and reduced in ethane relative to the rich LNG feed stream;
   c. collecting the lean LNG in a collection chamber;
   d. operating the LNG regasification process in a first operating state in which a lean LNG sendout stream is delivered to a sendout pipeline, wherein the lean LNG sendout stream comprises at least a portion of the lean LNG; and
   e. carrying out a heat exchange process comprising heat exchange between the lean LNG sendout stream and the overhead stream, such that the LNG sendout stream is heated and the overhead stream collected from the demethanizer is condensed.

2. The process of claim 1, wherein the heat exchange process further comprises heat exchange between the rich LNG feed stream, the lean LNG sendout stream and the overhead stream, such that the rich LNG feed stream is heated to an at least partially vaporized state for introduction into the demethanizer, the LNG sendout stream is heated and the overhead stream collected from the demethanizer is condensed, optionally wherein a portion of the rich LNG feed stream selectively bypasses the heat exchange process and is introduced directly to the demethanizer.

3. The process of any preceding claim, further comprising separating an inlet LNG feed stream into a first rich LNG stream and a second rich LNG stream, wherein the rich LNG feed stream comprises the first rich LNG stream; and introducing a first reflux flow in a liquid state into the demethanizer, the first reflux flow comprising the second rich LNG stream, optionally wherein, in response to a change in composition

of the LNG feed stream, adjusting a relative flow rate at which the first rich LNG stream and the first reflux flow are introduced into the demethanizer.

4. The process of any preceding claim, further comprising introducing a second reflux flow in a liquid state is flashed into the demethanizer, optionally wherein the second reflux stream comprises lean LNG from the collection chamber.

5. The process of any preceding claim, further comprising collecting a bottom stream from the demethanizer, wherein the bottom stream from the demethanizer comprises a natural gas liquid (NGL) enriched in ethane and reduced in methane relative to the LNG feed stream, optionally wherein the LNG regasification process recovers at least 99 vol% of the ethane from the LNG feed stream in the bottom stream from the demethanizer.

6. The process of any preceding claim, wherein the lean LNG sendout stream is sent to a vaporizer downstream of the heat exchange process, and then to the sendout pipeline.

7. The process of any preceding claim, further comprising operating the LNG regasification process in a second operating state in which at least a portion of the lean LNG is delivered to a holding tank, optionally further comprising operating the LNG regasification process in a third operating state in which at least a portion of the lean LNG is delivered to the sendout pipeline and at least a portion of the lean LNG is delivered to the holding tank, optionally further comprising operating the LNG regasification process in a fourth operating state in which at least a portion of the lean LNG is delivered to the sendout pipeline and at least a portion of the lean LNG is delivered to the holding tank, and wherein at least a portion of the lean LNG delivered to the holding tank is subsequently delivered to the sendout pipeline after delivery to the holding tank, and wherein at least a portion of the lean LNG delivered to the sendout pipeline is delivered to the sendout pipeline without first being delivered to the holding tank.

8. The process of claim 7, wherein, in the second, third and/or fourth operating state, the lean LNG is expanded in a liquid expander before delivery to the holding tank.

9. The process of any preceding claim, further comprising operating the demethanizer in a first operating mode and operating the demethanizer in a second operating mode, wherein, in the second operating mode the demethanizer is operated at a higher pressure than in the first operating mode.

10. A liquid natural gas (LNG) regasification process comprising a single column demethanizer process, comprising:

a. introducing a rich LNG feed stream, comprising a mixture of at least methane and ethane, in an at least partially vaporized state into a demethanizer;
b. condensing an overhead stream from the demethanizer, wherein the overhead stream comprises a lean LNG enriched in methane and reduced in ethane relative to the rich LNG feed stream;
c. collecting the lean LNG in a collection chamber;
d. operating the LNG regasification process in a first operating state in which at least a portion of the lean LNG is delivered to a sendout pipeline; and
e. operating the LNG regasification process in a second operating state in which at least a portion of the lean LNG is delivered to a holding tank.

11. The process of claim 10, further comprising operating the LNG regasification process in a third operating state in which at least a portion of the lean LNG is delivered to the sendout pipeline and at least a portion of the lean LNG is delivered to the holding tank, and/or further comprising operating the LNG regasification process in a fourth operating state in which at least a portion of the lean LNG is delivered to the sendout pipeline and at least a portion of the lean LNG is delivered the holding tank, and wherein at least a portion of the lean LNG delivered to the holding tank is subsequently delivered to the sendout pipeline after delivery to the holding tank, and wherein at least a portion of the lean LNG delivered to the sendout pipeline is delivered to the sendout pipeline without first being delivered to the holding tank.

12. The process of claim 10 or 11, wherein, in the second, third and/or fourth operating state, the lean LNG is expanded in a liquid expander before delivery to the holding tank.

13. A liquid natural gas (LNG) regasification system comprising a single column demethanizer system, comprising: a demethanizer arranged to receive at a first inlet of the demethanizer a rich LNG feed stream in an at least partially vaporized condition; the demethanizer operable to output at an overhead outlet an overhead stream comprising a lean LNG enriched in methane and reduced in ethane relative to the LNG feedstream; the demethanizer operable to output a bottom stream comprising natural gas liquid (NGL) enriched in ethane and reduced in methane relative to the LNG feed; a collection chamber oper-

able to receive the lean LNG; a sendout fluid pathway downstream of the collection chamber and arranged to deliver a lean LNG sendout stream to a lean LNG sendout; and a heat exchanger operable to carry heat exchange between the lean LNG sendout stream and the overhead stream, such that the LNG sendout stream is heated and the overhead stream output from the demethanizer is condensed.

14. The system of claim 13, wherein the heat exchanger is further operable carry out heat exchange between the rich LNG feed stream, the lean LNG sendout stream and the overhead stream, such that the rich LNG feed stream is heated to an at least partially vaporized state for introduction into the demethanizer, the LNG sendout stream is heated and the overhead stream output from the demethanizer is condensed.

15. The system of claim 13 or 14, wherein the system comprises at least one of:

a. a first fluid pathway fluidly coupling the lean LNG collection chamber to an inlet of the demethanizer,
b. a second fluid pathway fluidly coupling the lean LNG collection chamber to the lean LNG sendout,
c. a third fluid pathway fluidly coupling the lean LNG collection chamber to a holding tank,
d. a fourth fluid pathway fluidly coupling the holding tank to the lean LNG sendout,

wherein the second fluid pathway and/or the fourth fluid pathway comprises the sendout fluid pathway, optionally wherein the system is operable to selectively flow the lean LNG from the lean LNG collection chamber along one or more of the first, second, third, and fourth fluid pathways, when present.

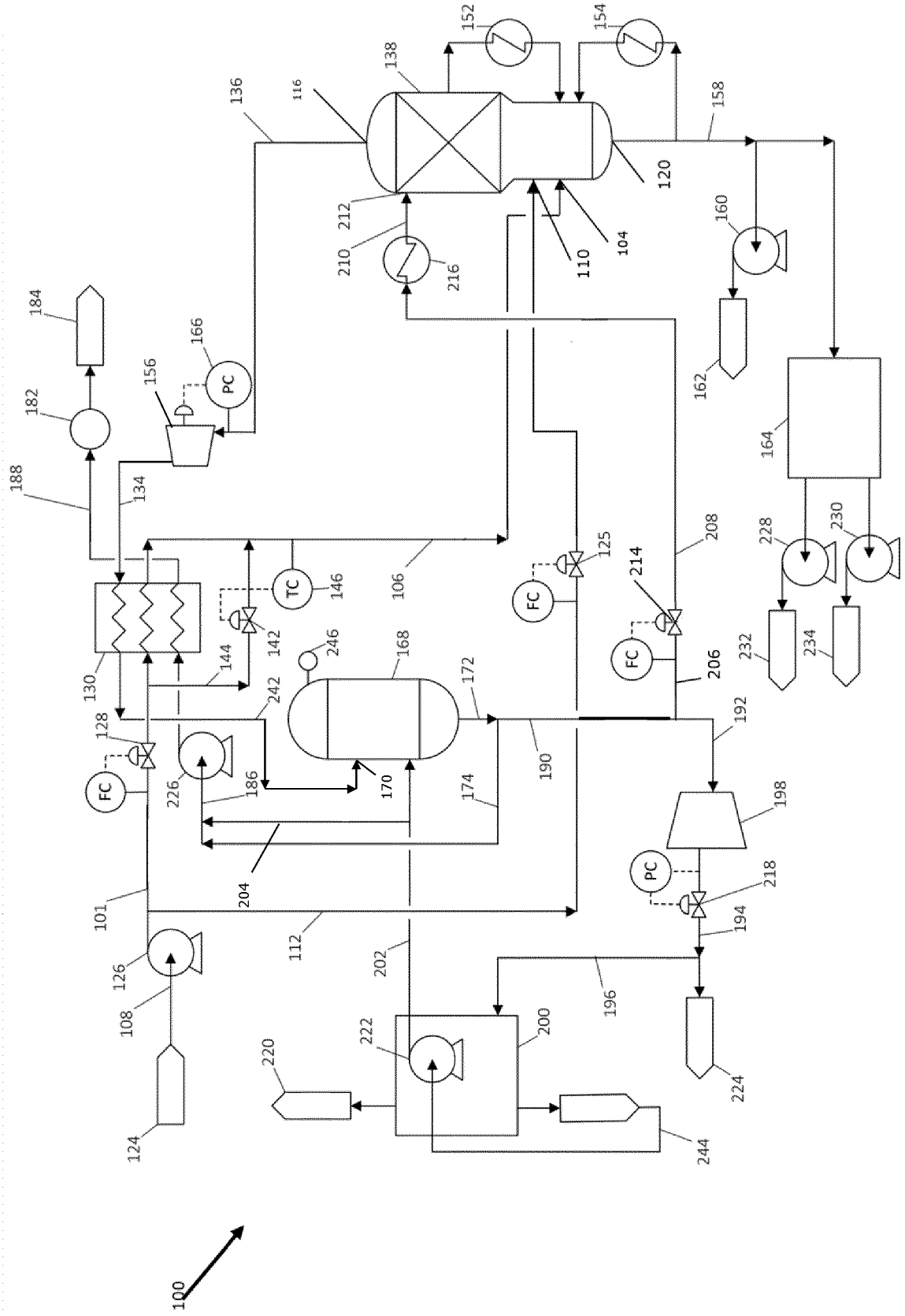

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Figure 1

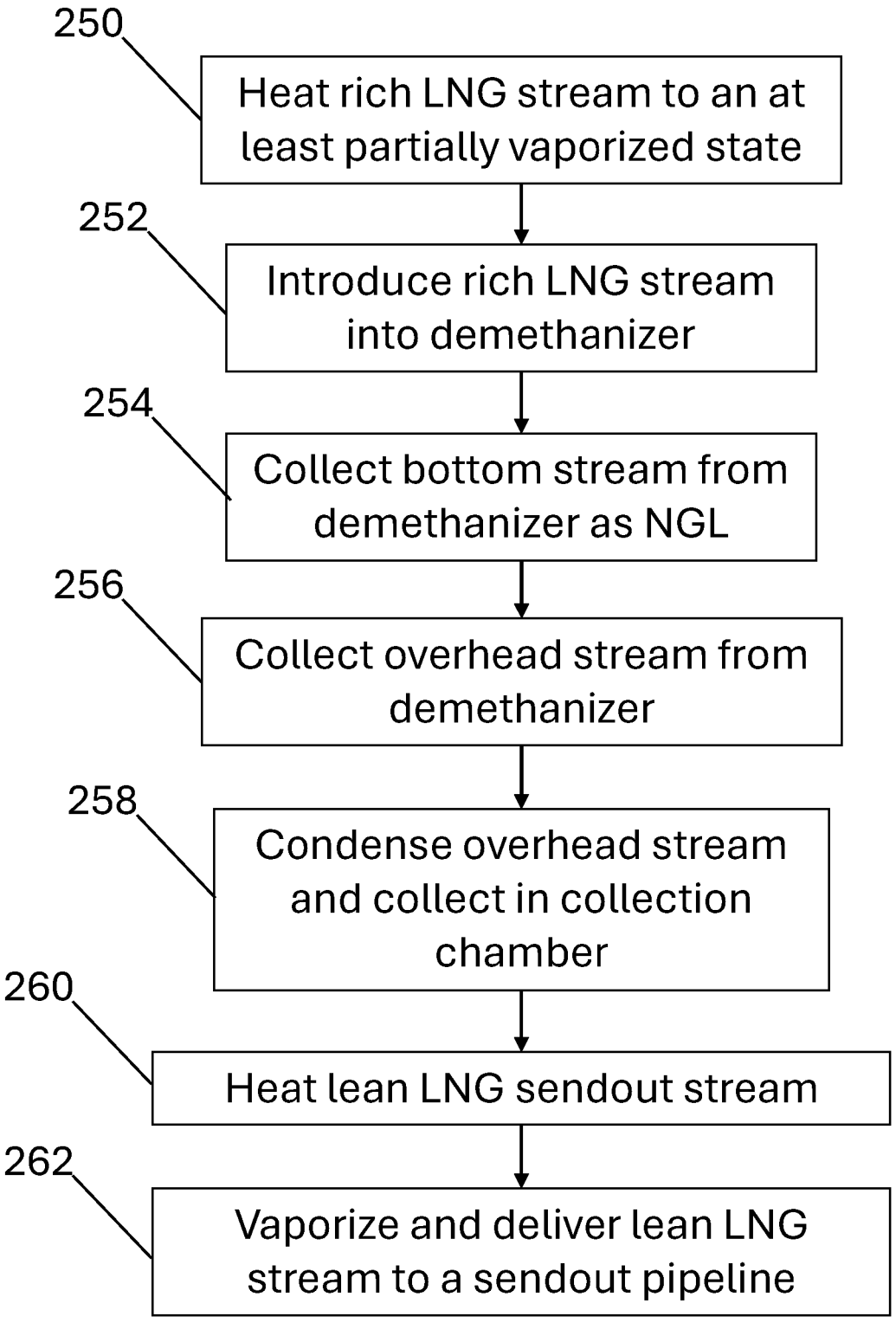

250
Heat rich LNG stream to an at least partially vaporized state
252
Introduce rich LNG stream into demethanizer
254
Collect bottom stream from demethanizer as NGL
256
Collect overhead stream from demethanizer
258
Condense overhead stream and collect in collection chamber
260
Heat lean LNG sendout stream
262
Vaporize and deliver lean LNG stream to a sendout pipeline

Figure 2

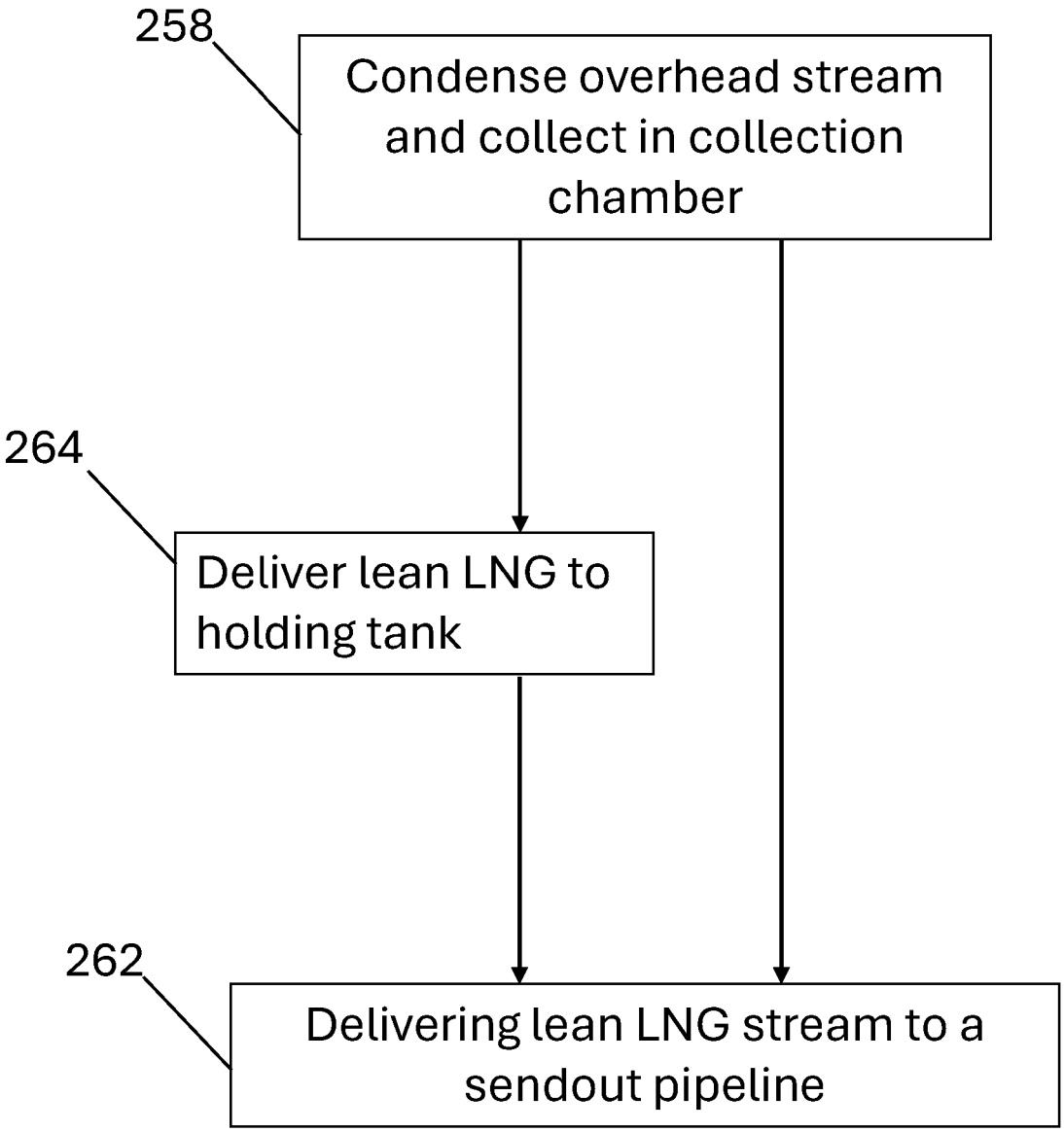

258
Condense overhead stream and collect in collection chamber
264
Deliver lean LNG to holding tank
262
Delivering lean LNG stream to a sendout pipeline

Figure 3

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PARTIAL EUROPEAN SEARCH REPORT

under Rule 62a and/or 63 of the European Patent Convention. This report shall be considered, for the purposes of subsequent proceedings, as the European search report

Application Number
EP 25 30 5497

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	WO 2022/203600 A1 (SINGAPORE LNG CORP PTE LTD [SG]) 29 September 2022 (2022-09-29) * page 11, line 17 - page 13, line 5; figures 1,2 *	1,3,5-9, 13,15 2,4,14	INV. F25J3/02
Y	US 3 420 068 A (PETIT PIERRE) 7 January 1969 (1969-01-07) * figure 5 *	2,14	
Y	ROSS F P ET AL: "Advanced technologies provide improved economics for liquefied natural gas facilities", HYDROCARBON PROCESSING, GULF PUBLISHING CO. HOUSTON, US, no. 1, 1 January 2008 (2008-01-01), pages 61-63, XP009098429, ISSN: 0018-8190 * figure 2 *	4	
A	KR 2009 0107935 A (DAEWOO SHIPBUILDING & MARINE ENG CO LTD) 14 October 2009 (2009-10-14) * figure 3 *	2,14	TECHNICAL FIELDS SEARCHED (IPC) F25J

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INCOMPLETE SEARCH

The Search Division considers that the present application, or one or more of its claims, does/do not comply with the EPC so that only a partial search (R.62a, 63) has been carried out.

Claims searched completely :

Claims searched incompletely :

Claims not searched :

Reason for the limitation of the search:

see sheet C

Place of search	Date of completion of the search	Examiner
Munich	1 December 2025	Göritz, Dirk

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04E07)

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PARTIAL EUROPEAN SEARCH REPORT

Application Number
EP 25 30 5497

DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (IPC)
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	
A	WINNINGHAM ET AL: "A cost effective process for NGL recovery from LNG", PROCEEDINGS GAS PROCESSORS ASSOCIATION. GPA MEETING/ANNUALCONVENTION, XX, XX, 1 September 2005 (2005-09-01), pages 1-21, XP007908436, * figure 3 *	3	
A	US 2007/204651 A1 (NANDA RAJEEV [US]) 6 September 2007 (2007-09-06) * paragraphs [0017] - [0018] *	9	TECHNICAL FIELDS SEARCHED (IPC)

EPO FORM 1503 03.82 (P04C10) 1

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INCOMPLETE SEARCH
SHEET C

Application Number
EP 25 30 5497

Claim(s) completely searchable:
1-9, 13-15

Claim(s) not searched:
10-12

Reason for the limitation of the search:

Claims 1 and 10 have been drafted as separate independent claims. Under Article 84 in combination with Rule 43(2) EPC an application may contain more than one independent claim in a particular category only if the subject matter claimed falls within one or more of the exceptional situations set out in paragraphs (a), (b) or (c) of Rule 43(2) EPC. This is not the case in the present application however, because it is evident that the subject-matter of said claims does neither involve a plurality of inter-related products, nor different uses of a product or apparatus. Furthermore, said claims appear to relate merely to various ways for re-gasifying LNG of the same process and are therefore no "alternative" solutions in the sense of different or even mutually exclusive possibilities.
The search has been restricted to the subject-matter indicated by the applicant in his letter of 28-11-2025 filed in reply to the invitation pursuant to Rule 62a(1) EPC.

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 25 30 5497

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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01-12-2025

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US 2007204651 A1	06-09-2007	NONE	

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82