

Methods, Apparatus And System For Utilising Cold Energy Recovered From A Liquefied Natural Gas Feed In A Natural Gas Liquid Extraction Process

- 5 The present application claims priority to Singapore patent application number 10202102929V titled ""METHODS, APPARATUS AND SYSTEM FOR UTILISING COLD ENERGY RECOVERED FROM A LIQUEFIED NATURAL GAS FEED IN A NATURAL GAS LIQUID EXTRACTION PROCESS" filed on 22 March 2021 which is incorporated by reference herein in its entirety.

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Technical Field

- The present invention is related to the integration of liquefied natural gas liquids production and liquified natural gas regasification, in particular the recovery of cold energy from a liquid natural gas feed and its use in the cooling process of lean
- 15 liquefied natural gas produced after/from extraction of natural gas liquids.

Background

- Natural gas (NG) is used as a fuel source and is commonly transported from the source in a liquid form as liquefied natural gas (LNG) due to the smaller volume
- 20 occupied by the LNG. Regasification of LNG occurs at the destination to supply the natural gas to the consumers via gas pipes.

- Natural gas and LNG both contain a mixture of C1 to C4 hydrocarbons depending on the source, with methane typically being the predominant component.
- 25 Depending on the LNG component mixture, the LNG may be termed lean LNG or rich LNG. Lean LNG typically contains a high content of methane with smaller quantities of other hydrocarbon like ethane. Compared to lean LNG, rich LNG has a lower methane content and a higher content of natural gas liquids (NGL) like ethane, propane, butane, and isobutane.

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Processes to extract the NGL from rich LNG to provide lean LNG have been previously developed. In the existing processes, the cold energy available from the rich LNG feed is typically fully utilised for distillation, condensation of reflux and

cooling of NGL product and is not able to re-liquefy the lean LNG. As a result, the lean LNG produced is often not suitable for storage in existing lean LNG storage tanks as there may be excessive loss of the lean LNG due to boil off gas and the produced lean LNG is often directly sent out to consumers regardless of the actual
5 consumer demand.

Summary

In a first aspect of the invention, there is provided a natural gas liquids (NGL) extraction process utilising cold energy recovered from a supplemental liquid natural
10 gas (LNG) feed, the process comprising: (i) separating NGL from a rich LNG feed to provide a lean LNG stream and a NGL stream; and (ii) performing a first thermal exchange between the lean LNG stream and the supplemental LNG feed in a supplemental heat exchanger, wherein the lean LNG stream is cooled and the supplemental LNG feed is heated, wherein the supplemental LNG feed is distinct
15 from the rich LNG feed.

Preferably, the process further comprises performing a second thermal exchange between the lean LNG stream and the rich LNG feed in a first heat exchanger prior to separating NGL from the rich LNG feed, wherein the lean LNG stream is cooled
20 and the rich LNG feed is heated. More preferably, performing the second thermal exchange further occurs in a second heat exchanger between the lean LNG stream and the rich LNG feed, the second heat exchanger being distinct from the first heat exchanger, wherein the lean LNG stream is cooled and the rich LNG feed is heated, wherein performing the second thermal exchange comprises feeding the rich LNG
25 feed sequentially into the first heat exchanger and the second heat exchanger; and feeding the lean LNG stream sequentially into the second heat exchanger and the first heat exchanger.

In an embodiment, the second thermal exchange is performed after the first thermal
30 exchange with respect to a flow of the lean LNG stream. The lean LNG stream exits the distillation column and flows into the supplemental heat exchanger for the first thermal exchange, and subsequently flows into the first heat exchanger and second heat exchanger (if present) to perform the second thermal exchange.

In an embodiment, the first thermal exchange is performed after the second thermal exchange with respect to a flow of the lean LNG stream. Preferably, performing the second thermal exchange further occurs in a second heat exchanger between the lean LNG stream and the rich LNG feed, the second heat exchanger being distinct
5 from the first heat exchanger, wherein the second thermal exchange is performed again after the first thermal exchange, and performing the second thermal exchange comprises feeding the rich LNG feed sequentially into the first heat exchanger and the second heat exchanger; and feeding the lean LNG stream sequentially into the second heat exchanger, the supplemental heat exchanger, and the first heat
10 exchanger to allow the second thermal exchange to be performed again after the first thermal exchange. More preferably, separating NGL from the rich LNG feed occurs in a distillation column, the process further comprising diverting a portion of the rich LNG feed to the distillation column before the rich LNG feed enters the second heat exchanger. The lean LNG stream exits the distillation column and flows
15 into the first heat exchanger for the second thermal exchange, and subsequently flows into the supplemental heat exchanger for the first thermal exchange, and the second heat exchanger (if present) to perform the second thermal exchange again. The supplemental heat exchanger may be interposed between the first and second heat exchangers performing the second heat exchange. Advantageously, when a
20 cold supplementary LNG feed from a LNG regasification terminal is utilised in the supplemental heat exchanger, the supplemental heat exchanger and the second heat exchanger may be located within the LNG regasification terminal and allows the heat exchange process to be better controlled (for example, the minimised distance between the heat exchangers and thus process reaction time) to avoid or
25 minimise any impact to the natural gas send out at the regasification terminal side (for example, to prevent the supplementary LNG stream from not being sufficiently warmed due to a disruption in the NGL extraction side).

Preferably, the process further comprises compressing the lean LNG stream before
30 performing the second thermal exchange. Where the first thermal exchange is interposed between separate instances of the second thermal exchange, the compression is preferably done before the second thermal exchange occurs the first time.

In an embodiment, separating NGL from the rich LNG feed occurs in a distillation column, the process further comprising separating a liquid residue from the lean LNG stream cooled from the first thermal exchange to provide a second lean LNG stream; compressing the second lean LNG stream before performing the second
5 thermal exchange; and feeding the liquid residue back to the distillation column.

Preferably, the supplemental LNG feed is a lean LNG feed.

Preferably, the first and/or second thermal exchange reliquefies the lean LNG
10 stream to provide a reliquefied lean LNG suitable for storage in a liquefied LNG storage tank, and the reliquefied lean LNG has a temperature of -150 °C or lower. More preferably, the process comprises reducing a pressure of the reliquefied lean LNG.

15 Preferably, at least one of the following conditions are met:

- (i) the process further comprising collecting the separated NGL;
- (ii) the process further comprising sending the supplemental LNG feed to a vaporiser for regasification after the first thermal exchange;
- (iii) the process further comprising pumping the rich LNG feed for the second
20 thermal exchange using a booster pump;
- (iv) the separated NGL comprises alkanes with 2 or more carbon atoms.

In a second aspect of the invention, there is provided a natural gas liquids (NGL) extraction apparatus configured to utilise cold energy recovered from a
25 supplemental liquid natural gas (LNG) feed, the apparatus comprising a distillation column configured to separate NGL from a rich LNG feed to provide a lean LNG stream and a NGL stream; a supplemental heat exchanger configured to receive the lean LNG stream from the distillation column and to allow for a first thermal exchange between the lean LNG stream and the supplemental LNG feed, wherein
30 the lean LNG stream is cooled thereby providing a cooled lean LNG stream and the supplemental LNG feed is heated, and wherein the supplemental heat exchanger is devoid of the rich LNG feed.

Preferably, the apparatus further comprises a thermal exchange means configured to perform a second thermal exchange between the lean LNG stream and the rich LNG feed prior to the rich LNG feed entering the distillation column, wherein at the thermal exchange means the lean LNG stream is cooled and the rich LNG feed is heated, the thermal exchange means comprising a first heat exchanger. More preferably, the thermal exchange means comprises a second heat exchanger which is distinct from the first heat exchanger, wherein the first heat exchanger and the second heat exchanger are configured and arranged to allow the rich LNG feed to be fed sequentially into the first heat exchanger and the second heat exchanger, and to allow the lean LNG stream to be fed sequentially into the second heat exchanger and the first heat exchanger, for the second thermal exchange to be performed.

In an embodiment, the supplemental heat exchanger and thermal exchange means are arranged such that the second thermal exchange is performed after the first thermal exchange with respect to the flow of the lean LNG stream.

In an embodiment, the supplemental heat exchanger and thermal exchange means are arranged such that the first thermal exchange is performed after the second thermal exchange with respect to the flow of the lean LNG stream. In an embodiment, the thermal exchange means comprises a second heat exchanger which is distinct from the first heat exchanger, wherein the first heat exchanger and the second heat exchanger are configured and arranged to allow the rich LNG feed to be fed sequentially into the first heat exchanger and the second heat exchanger, and to allow the lean LNG stream to be fed sequentially into the second heat exchanger, the supplemental heat exchanger, and the first heat exchanger, to allow the second thermal exchange to be performed again after the first thermal exchange. Preferably, the apparatus further comprises a flow path to allow a portion of the rich LNG feed to be diverted to the distillation column before the rich LNG feed enters the second heat exchanger.

Preferably, the apparatus further comprises a compressor configured to compress the lean LNG stream before entering the thermal exchange means. Where the supplemental heat exchanger is interposed between the first and second heat

exchangers, the compressor is preferably placed before the lean LNG stream enters the second heat exchanger.

In an embodiment, the apparatus further comprises a reflux drum and a compressor,
5 the reflux drum configured to:

- (i) receive the cooled lean LNG stream from the supplemental heat exchanger;
 - (ii) separate a liquid residue from the cooled lean LNG stream to provide a second lean LNG stream;
 - (iii) feeding the second lean LNG stream to the compressor;
 - 10 (iv) feeding the liquid residue to the distillation column,
- wherein the compressor is configured to compress the second lean LNG stream before entering the thermal exchange means, and wherein the distillation column is configured to receive the liquid residue from the reflux drum.

15 Preferably, the supplemental LNG feed is a lean LNG feed.

Preferably, the first and/or second thermal exchanger reliquefies the lean LNG stream to provide a reliquefied lean LNG, the apparatus comprising at least one of the following:

- 20 (i) a storage tank to receive and store the reliquefied lean LNG;
- (ii) a release valve configured to reduce the pressure of the reliquefied lean LNG before transfer to the storage tank;
- (iii) at least part of the re-liquefied lean LNG is used as the supplemental LNG feed;
- 25 (iv) a collection outlet in the distillation column to collect the separated NGL;
- (v) a booster pump configured to transfer the rich LNG feed to the thermal exchange means.

In a third aspect of the invention, there is provided a LNG terminal facility comprising
30 the apparatus according to the second aspect above, a supplemental LNG storage tank configured to provide the supplemental LNG feed, and a vaporiser configured to regasify the supplemental LNG feed after the supplemental LNG feed is heated by the supplemental heat exchanger.

Description of Drawings

Figure (Fig.) 1 shows a schematic layout of an embodiment of the invention.

Fig. 2 shows a schematic layout of another embodiment of the invention.

5 Detailed Description of Embodiments of the Invention

In the following description, numerous specific details are set forth in order to provide a thorough understanding of various illustrative embodiments of the invention. It will be understood, however, to one skilled in the art, that embodiments of the invention may be practiced without some or all of these specific details.

10 Embodiments described in the context of one of the methods or apparatuses are analogously valid for the other methods or apparatuses. Similarly, embodiments described in the context of a method are analogously valid for an apparatus, and vice versa.

15 Unless defined otherwise or the context clearly dictates otherwise, all technical and Scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. Although any methods and materials similar or equivalent to those described herein can be used in the practice or testing of the invention, the preferred methods and materials are now
20 described.

As used herein, the articles “a”, “an” and “the” as used with regard to a feature or element include a reference to one or more of the features or elements. As used herein, the term “and/or” includes any and all combinations of one or more of the
25 associated listed items. As used herein, the terms “first,” “second,” and “third,” etc. are used merely as labels, and are not intended to impose numerical or chronological requirements on their objects. As used herein, the terms “top”, “bottom”, “left”, “right”, “side”, “vertical” and “horizontal” are used to describe relative arrangements of the elements and features. As used herein, the term “each other”
30 denotes a reciprocal relation between two or more objects, depending on the number of objects involved.

Where a range of values is recited, it is to be understood that each intervening integer value, and each fraction thereof, between the recited upper and lower limits

of that range is also specifically disclosed, along with each subrange between such values. The upper and lower limits of any range can independently be included in or excluded from the range, and each range where either, neither or both limits are included is also encompassed within the invention.

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Ranges may be expressed herein as from "about" one particular value, and/or to "about" another particular value. When such a range is expressed, a further aspect includes from the one particular value and/or to the other particular value. Similarly, when values are expressed as approximations, by use of the antecedent "about," it will be understood that the particular value forms a further aspect. It will be further understood that the endpoints of each of the ranges are significant both in relation to the other endpoint, and independently of the other endpoint. It is also understood that there are a number of values disclosed herein, and that each value is also herein disclosed as "about" that particular value in addition to the value itself. For example, if the value "10" is disclosed, then "about 10" is also disclosed. It is also understood that each unit between two particular units are also disclosed. For example, if 10 and 15 are disclosed, then 11, 12, 13, and 14 are also disclosed.

Although each of these terms has a distinct meaning, the terms "comprising", "consisting of" and "consisting essentially of" may be interchanged for one another throughout herein. The term "having" or "including" has the same meaning as "comprising" and may be replaced with either the term "consisting of" or "consisting essentially of". As used herein, the phrases "configured to", "arranged to", "adapted to", "constructed and arranged to" may be used interchangeably.

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The terms "heat" and "thermal" are used interchangeably herein unless stated otherwise, and likewise the corresponding terms for example, "heat energy" and "thermal energy", "heat exchange" and "thermal exchange".

30 Terms such as "coupled", "connected", "attached", "conjugated and "linked" are used interchangeably herein and encompass direct as well as indirect connection, attachment, linkage or conjugation unless the context clearly dictates otherwise. In the drawings, linking arrows between components denote coupling of the

components, e.g. to facilitate fluid communication according to the illustrated arrow direction.

As used herein, rich LNG is considered to be LNG with wobbe index of >51.5 MJ/Sm³ and lean LNG as LNG with wobbe index ≤ 51.5 MJ/Sm³ where Sm³ refers to standard cubic metre.

The apparatus and system described herein contain various components which may be connected with piping to allow fluid transfer between the components as described. Pumps, controllers, gauges, and valves may be used as necessary to achieve the described flow and processes described herein.

Fig. 1 shows a schematic layout of an embodiment in which two LNG processes – a LNG regasification process and a NGL extraction process - are integrated in a system 100 to work with each other to provide an energy efficient process. In one example, these two LNG processes may be performed within a LNG terminal facility.

A LNG feed (or may also be referred to as supplemental LNG feed) from a LNG storage tank 5, which may contain lean LNG, may be sent for regasification in an open rack vaporiser (ORV) 10 via heat exchanger A 55 (or may be referred to as supplemental heat exchanger). As the supplemental LNG feed from the storage tank 5 flows through heat exchanger A 55, it is heated and serves as a coolant in heat exchanger A 55. As a result, a portion of the cold energy is recovered from the supplemental LNG feed before it reaches the vaporiser 10 for regasification to be sent out to consumers. The supplemental LNG feed may be used for purposes other than regasification as long as it is able to act as the coolant in heat exchanger A 55.

In the NGL extraction process, a rich LNG storage tank 15 is coupled to a high pressure booster pump 20. The booster pump 20 feeds the rich LNG from the rich LNG storage tank 15 sequentially to heat exchanger B 25 (may also be referred to as a lean NG condenser) and heat exchanger C 30 (may also be referred to as a lean NG cooler). The rich LNG feed is heated in both heat exchanger B 25 and heat exchanger C 30 and thus acts as the coolant in both heat exchanger B 25 and heat exchanger C 30. An advantage of having two heat exchangers is more efficient use

of temperature approaches to maximize the cold energy recovery from the rich LNG feed and the supplemental LNG feed. Alternatively, heat exchanger B 25 and heat exchanger C 30 may be combined as or replaced by a single heat exchanger.

- 5 The heated rich LNG feed exits the heat exchanger C 30 and is fed into a distillation column 40 (may also be referred to as a demethaniser column). The rich LNG feed may be further heated by a heater 35 to further raise its temperature before entering the distillation column 40. The heater 35 may use glycol in a low grade heating loop. The low grade heating loop may include air heaters, circulation pumps and an
10 expansion vessel. As an example, the rich LNG feed may be heated to between -69 °C (richest) to -84 °C (leanest) for distillation, and may be partially vaporised through the heating process.

- In the distillation column 40, the rich LNG feed is heated to produce or separate into
15 a lean LNG stream and a liquid residue (or a NGL stream) containing natural gas liquids (NGL) which mainly comprise ethane, propane, butane and isobutane. The operating temperature of the distillation column depends on the composition of the rich LNG feed. As an example, the distillation column 40 may operate at a temperature of between -86 °C (richest) to -95 °C (leanest) with an approximate
20 pressure of 21 bar (richest). A reboiler 45 may be coupled to the bottom part of the distillation column 40 for effective distillation. The reboiler 45 may use hot water from a high-grade heating loop. The high grade heating loop may include a high voltage (HV) electrode heater, circulation pumps and an expansion vessel. Reboiler 45 may also be heated by air in a circulating glycol heating medium loop. As an
25 example, the temperature at the reboiler outlet may be approximately -12 °C. The distillation column 40 may have the following specifications: 1.5 mol% C1 in C2, surface tension greater than 2 dyne/cm, L/V density ratio greater than 5, and a density difference greater than 350 kg/m³.

- 30 The liquid residue (NGL stream) may be collected from the bottom part of the distillation column 40 via a liquid residue outlet 50. Pump(s) may be used to collect the liquid residue and may operate at approximately 43 Barg and/or 3.5 Barg above bubble points at the off-take points. The liquid residue outlet 50 may be coupled to a storage tank for storing the NGL or the liquid residue may be pumped via pipes to

deliver the liquid residue directly to a consumer of the liquid residue, for example as petrochemical feedstocks.

5 The lean LNG stream exits from the top part of the distillation column 40 and is in a vapour state, although it may be possible for a liquid state to be present in a small fraction. It may be necessary to reliquefy the lean LNG stream exiting the top part of the distillation column 40 for storage to allow the lean LNG to be used later for export or to be released to the units requiring the LNG. The lean LNG stream is cooled in heat exchanger A 55 by the supplemental LNG feed. In other words, the lean LNG
10 stream provides thermal energy to heat up the supplemental LNG feed. Thermal exchange between the lean LNG stream and the supplemental LNG feed results in heating of the supplemental LNG feed and cooling of the lean LNG stream. If sufficient cold energy is provided by the supplemental LNG feed, it is possible that the lean LNG stream may be liquefied and thereafter may be sent to a lean LNG
15 storage tank.

It is likely that additional cooling to that provided by the supplemental LNG feed will be required to reliquefy the lean LNG stream from the distillation column 40 to reliquefy the lean LNG to suitable storage conditions. A thermal exchange between
20 the lean LNG stream and the rich LNG feed prior to separating the NGL from the rich LNG feed (in other words before the rich LNG feed is fed into the distillation column 40) may be performed in a thermal exchange means to provide additional cooling for the lean LNG stream to reliquefy the lean LNG stream. The thermal exchange between the lean LNG feed and the rich LNG feed may be performed in
25 a single stage or two or more stages which provides flexibility to alter the system to provide a balance between recover of the reliquefied LNG, NGL and costs. In an embodiment, the thermal exchange means comprise either or both of heat exchanger B 25 and heat exchanger C 30.

30 The cooled LNG stream exits the heat exchanger A 55 (may also be referred to as a reflux recondenser) and is sent to a reflux drum 60. As the lean LNG stream exiting the distillation column 40 and/or heat exchanger A 55 may contain a mixture of liquid and gas, the reflux drum 60 allows for further separation of the liquid and gas mixture. The liquid portion from the mixture in the reflux drum 60 may be fed back

to the distillation column 40 to be recycled via reflux pumps to improve separation efficiency. The mainly gaseous portion from the mixture in the reflux drum 60 (or second lean LNG stream) may be fed into a compressor 65.

- 5 The compressor 65 compresses the gaseous portion of the lean LNG stream to provide a compressed lean LNG stream which is subsequently fed sequentially to the heat exchanger C 30 and the heat exchanger B 25. Thermal exchange between the compressed lean LNG stream and the rich LNG feed cools the lean LNG stream and heats the rich LNG feed at heat exchanger B 25 and heat exchanger C 30. The
- 10 rich LNG feed and compressed lean LNG stream may enter the heat exchanger B 25 and heat exchanger C 30 in different or other sequences to maximise the thermal transfer between them and allow for more efficient heat exchange. As explained above, in an alternative embodiment, a single heat exchanger may be used in place of heat exchanger C 30 and heat exchanger B 25. The thermal exchange between
- 15 the lean LNG stream and the rich LNG feed, which takes place at heat exchanger C 30 and/or heat exchanger B 25, is performed after the thermal exchange between the lean LNG stream and the supplemental LNG feed which takes place at heat exchanger A 55.
- 20 In an embodiment, the lean LNG stream is re-liquefied by heat exchanger B 25 and/or heat exchanger C 30. The re-liquefied lean LNG may be sent to a lean LNG storage tank 75 for storage. The re-liquefied lean LNG may have a temperature of -150 °C or lower, for example -159 °C or lower. Before the re-liquefied lean LNG enters the storage tank 75, a valve 70 (for example a JT valve) may be used to
- 25 reduce pressure of the re-liquefied LNG to the desired pressure in the lean LNG storage tank 75. Advantageously, the re-liquefied LNG produced by the process may be stored in an existing lean LNG storage tank 75 with minimal loss due to boil off gas.
- 30 In an embodiment, all or a portion of the re-liquefied lean LNG produced from the NGL extraction and reliquefaction process may be transferred to the supplemental heat exchanger A 55 to be used as the supplemental LNG feed. In an alternative embodiment, the re-liquefied lean LNG produced from the NGL extraction process may be transferred to the lean LNG storage tank 75 and thereafter the supplemental

LNG feed may be drawn from the lean LNG storage tank 75 (e.g. supplemental LNG feed tank 5 includes or is coupled to lean LNG storage tank 75). In another embodiment, the supplemental LNG feed may include the re-liquefied LNG produced from the NGL extraction process as well as lean LNG feed from the storage tank 75, other storage tank, other process, or any combination thereof.

A booster pump 20 may be provided to assist in the transfer of the rich LNG feed from the rich LNG storage tank 15 to the thermal exchange means and to provide the pressure required for efficient separation in the distillation column 40. A heater 35 may be provided to further heat the rich LNG feed before it enters the distillation column 40. In the distillation column, the NGL and lean LNG are separated to provide a lean LNG stream and a NGL stream. The NGL stream may be collected via the liquid residue outlet 50 at the bottom portion of the distillation column 40, while the lean LNG stream exits via the top portion of the distillation column 40.

Fig. 2 shows a schematic layout of another embodiment of a system 100 integrating the two LNG processes – LNG regasification process and NGL extraction process. The embodiment in Fig. 2 provides a modified system with fewer components and a different cooling sequence for the lean LNG stream from the distillation column 40. The lean LNG stream first undergoes thermal exchange with the rich LNG feed before undergoing thermal exchange with the supplemental LNG feed and a further thermal exchange with the rich LNG feed. Thus, the thermal exchange between the lean LNG stream and the rich LNG feed may be split into two (or more) stages which interpose the thermal exchange with the supplemental LNG feed. Hence, the lean LNG feed is first cooled by the rich LNG feed followed by the supplemental LNG feed, and subsequently cooled again by the rich LNG feed. This allows for reduced heat exchanger capacity and overall reduction in capex.

In the embodiment in Fig. 2, the lean LNG stream exits the distillation column 40 and is passed into a compressor 65. The compressed lean LNG stream is subsequently fed into the heat exchanger C 30 where thermal exchange occurs with the rich LNG feed before the rich LNG feed enters the distillation column 40. Thus, the compressed lean LNG stream is cooled while the rich LNG feed is heated.

The lean LNG stream exits heat exchanger C 30 and is subsequently fed into the heat exchanger A 55 where thermal exchange occurs with the supplemental LNG feed. Thermal exchange between the lean LNG stream and the supplemental LNG feed results in heating of the supplemental LNG feed and cooling of the lean LNG stream. The thermal exchange between the lean LNG stream and the supplemental LNG feed, which takes place at heat exchanger A 55, is performed after the thermal exchange between the lean LNG stream and the rich LNG feed which takes place at heat exchanger C 30.

The cooled lean LNG stream exits heat exchanger A 55 and may be further fed into the heat exchanger B 25 where thermal exchange occurs between the lean LNG stream and the rich LNG feed from the rich LNG storage tank 15 that is to be heated for feeding to the distillation column 40. Upon exiting heat exchanger B 25, the lean LNG stream would likely be re-liquefied and may be sent to a lean LNG storage tank 75 for storage. The rich LNG feed is heated in heat exchanger B 25 and is subsequently fed into heat exchanger C 30 for the thermal exchange with the compressed lean LNG stream from the distillation column 40, after which the rich LNG feed is fed into the distillation column 40. Compared to the embodiment in Fig. 1, the embodiment in Fig. 2 does not use a heater 35 (to heat the rich LNG feed prior to entry into the distillation column 40) and a reflux drum 60. The embodiment in Fig. 2 may be similarly provided with a booster pump 20, a boiler 45, a liquid residue outlet 50, vaporiser 10 and LNG storage tank 75. For the embodiment in Fig. 2, the thermal exchange between the lean LNG stream and the rich LNG feed is performed twice (or in two stages), i.e. one time each at heat exchanger C 30 and heat exchanger B 25, with the thermal exchange between the lean LNG stream and the supplemental LNG feed, which takes places at heat exchanger A 55, performed in between. Thus, the thermal exchange between the lean LNG stream and rich LNG feed may occur in two stages before and after the thermal exchange between the lean LNG stream and the supplemental LNG feed.

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In the embodiment in Fig. 2, the booster pump 20 may be placed between the heat exchanger B 25 and heat exchanger C 30 instead of before the heat exchangers 25, 30 in the embodiment in Fig. 1. In this embodiment, the booster pump 20 will boost the pressure of the rich LNG feed exiting the heat exchanger B 25 and

entering heat exchanger C 30. A portion of the rich LNG feed may be taken from the pump 20 discharge and diverted to the distillation column 40 as a reflux flow via flow path 80 to the top section of the distillation column 40 to improve separation efficiency.

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In both embodiments shown in Fig. 1 and Fig. 2, the supplemental LNG feed flows from the LNG storage tank 5 to the supplemental heat exchanger A 55 where the supplemental LNG feed is heated and flows to the vaporiser 10 or other suitable unit that utilises the supplemental LNG. The rich LNG feed flows from the rich LNG storage tank 15 to be heated in the thermal exchange means (for example, heat exchanger B 25 and heat exchanger C 30) before the rich LNG feed enters the distillation column 40.

In the embodiment in Fig. 1, the lean LNG stream from the distillation column 40 is first cooled in the supplemental heat exchanger A 55 before it is fed into the reflux drum 60 where another separation occurs to provide a mainly liquid stream which is fed back to the distillation column 40 and a mainly gaseous stream (i.e. a second lean LNG stream) which is fed to the compressor 65. The gaseous portion of the lean LNG stream is compressed by the compressor 65 before it enters the thermal exchange means. The lean LNG stream is first fed into the heat exchanger C 30 and subsequently into the heat exchanger B 25, after which the lean LNG stream should be re-liquefied and suitable for storage in the lean LNG storage tank 75. Thus, the order in which the rich LNG feed is fed to the heat exchanger B 25 and heat exchanger C 30 is reversed to the order the compressed lean LNG stream is fed.

In the embodiment in Fig. 2, the lean LNG stream from the distillation column 40 is first fed to the compressor 65 and cooled in the thermal exchange means, for example heat exchanger C 30, by the rich LNG feed. The lean LNG stream is subsequently fed to the supplemental heat exchanger A 55 for thermal exchange between the lean LNG stream and the supplemental LNG feed. The lean LNG stream exits the supplemental heat exchanger A 55 and is fed back to the second stage of the thermal exchange means, for example heat exchanger B 25, for an additional cooling by the rich LNG feed, after which the lean LNG stream should be

re-liquefied and suitable for storage in the lean LNG storage tank 75. Thus, the difference in both embodiments, lie in the sequence the lean LNG stream exiting the distillation column is cooled by the various thermal exchanges, with the Fig. 2 embodiment having fewer components while maintaining almost the same separation and recovery efficiencies for the NGL and the reliquefied lean LNG. In the event that the NGL extraction facility is integrated with a LNG regasification Terminal, the embodiment shown in Fig. 2 has the advantage of improved operation reliability by allowing heat exchangers A 55 and B 25 to be located within the LNG regasification Terminal.

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As an example, considering the embodiment in Fig.1, 1.5 to 3 MTPA (million tonnes per annum) of lean LNG feed for regasification may be used as the supplemental LNG feed. The estimated cold energy transferred by heat exchanger A 55 is about 4.8 MWt. The rich LNG feed may use about 2.25 MTPA as the feed train. The cold energy provided in heat exchanger B 25 and heat exchanger C 30 is about 28.5 MWt and 11.4 MWt respectively. The total cold duty of the three heat exchangers is about 44.7 MWt and the total electrical power required for the whole NGL extraction and re-liquefaction is approximately 5 MWe. It is estimated that the process potentially provides a carbon credits equivalent of 14,000 tpy (tonnes per year) of carbon abatement.

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As another example, considering the embodiment in Fig.2, the total electrical power required is approximately 4.5 MWe; estimated cold energy transferred by heat exchanger A 55 is about 6 MWt; the cold energy provided in heat exchanger B 25 and heat exchanger C 30 is about 7.4 MWt and 18.7 MWt respectively giving rise to a total cold duty of 32 MWt. For this example, the process potentially provides a carbon credits equivalent of 5,000 tpy (tonnes per year) of carbon abatement. Thus, the integrated process described herein is energy efficient and environmentally friendly.

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Heat exchangers A, B, C (55, 25, 30) described above may be any suitable heat exchanger. Examples include brazed aluminium heat exchangers (BAHE), shell and tube heat exchangers and printed circuit heat exchangers. The storage tanks used for the rich LNG, lean LNG, and supplemental LNG may be any suitable tank

The NGL extraction process and apparatus may be integrated with a LNG regasification process and apparatus in the LNG terminal or facility. The feed for the LNG regasification process may serve as the supplemental LNG feed, and may be lean LNG or rich LNG that is being sent for regasification. As described above, the lean LNG produced by the NGL extraction process may be reliquefied and stored in lean LNG storage tanks with lean LNG from other sources or processes. The reliquefied lean LNG from the NGL extraction process may be used as desired by the LNG facility operator including exporting the lean LNG to other facilities and regasification of the lean LNG to send out to the consumers. The lean LNG may even act as the supplemental LNG feed as described in the NGL extraction process above. This provides the LNG facility operator with flexibility to determine how best to meet the demand requirements of lean LNG globally instead of being restricted to nearby consumers. Advantageously, the reliquefied lean LNG has suitable temperature and pressure to be stored in the existing lean LNG storage tanks with minimal boil-off gas and do not require specific storage tanks to be constructed separately. Advantageously, the integration of the NGL extraction process and LNG regasification process provides for a more efficient and cost-effective operation by utilising the cold energy from the LNG regasification and in combination with the cold energy of the rich LNG feed to reliquefy the lean LNG produced from the NGL extraction process. The integration provides for carbon savings in the form of reduced energy expenditure providing a more environmentally friendly process and system.

Example of possible operating conditions of the embodiments in Figs. 1 and 2 described above are set out below in Table 1.

Table 1: Operating Conditions of Embodiments in Figs. 1 and 2

Parameter	Embodiment in Fig. 1	Embodiment in Fig. 2
Demethaniser column feed temperature, °C	-87.3 (average)	-80 (average)
Demethaniser Overhead Pressure, kPa	2120	1700
Lean NG Compressor discharge pressure, kPa	4500	3200

Reboiler Outlet Temperature, °C	11.9	4.2
C2+ Recovery, mol %	95	95
LNG Recovery at LNG tank conditions, mass %	95	95
NG export pressure, kPa	4500	4500
NG export temperature, °C	13	13
LNG export pressure, kPa	115	114
LNG Export temperature, °C	-154	-155
C2+ export pressure, kPa	4380	4000
C2+ export temperature, °C	ambient	ambient

As may be seen from the example operating parameters in Table 1, the embodiments in Figs. 1 and 2 allow for different operating temperatures and pressures in the various components and streams of the process and apparatus.

- 5 Both embodiments provide similar LNG recovery efficiency of 95% and greater at LNG storage tank conditions. The C2+ product recovery for both embodiments are similarly efficient and provides the NGL stream in a liquid state in non-insulated pipes.
- 10 Advantageously, the embodiment in Fig. 2 utilises fewer components (e.g. a reflux drum and heater is omitted) than the embodiment in Fig. 1 which provides cost savings and improved operation reliability. Operation reliability for the embodiment shown in Fig. 2 is improved as there are less components to maintain and operate (for example, removal of reflux drum 60 and reflux pump(s)). Moreover with respect
- 15 to utilising a cold supplementary LNG feed from a LNG regasification terminal in heat exchanger A 55, the heat exchangers A 55 and B 25 may be located within the LNG regasification terminal and allows the heat exchange process to be better controlled (for example, the minimised distance between the heat exchangers and thus process reaction time) to avoid or minimise any impact to the natural gas send
- 20 out at the regasification terminal side (for example, to prevent the supplementary LNG stream from not being sufficiently warmed due to a disruption in the NGL extraction side).

Claims

1. A natural gas liquids (NGL) extraction process utilising cold energy recovered from a supplemental liquid natural gas (LNG) feed, the process comprising:
 - (i) separating NGL from a rich LNG feed to provide a lean LNG stream and a NGL stream; and
 - (ii) performing a first thermal exchange between the lean LNG stream and the supplemental LNG feed in a supplemental heat exchanger, wherein the lean LNG stream is cooled and the supplemental LNG feed is heated, wherein the supplemental LNG feed is distinct from the rich LNG feed and is provided from a supplemental LNG storage tank, wherein the rich LNG feed is provided by a rich LNG storage tank.
2. The process according to claim 1 comprising performing a second thermal exchange between the lean LNG stream and the rich LNG feed in a first heat exchanger prior to separating NGL from the rich LNG feed, wherein the lean LNG stream is cooled and the rich LNG feed is heated.
3. The process according to claim 2 wherein performing the second thermal exchange further occurs in a second heat exchanger between the lean LNG stream and the rich LNG feed, the second heat exchanger being distinct from the first heat exchanger, wherein the lean LNG stream is cooled and the rich LNG feed is heated, wherein performing the second thermal exchange comprises feeding the rich LNG feed sequentially into the first heat exchanger and the second heat exchanger; and feeding the lean LNG stream sequentially into the second heat exchanger and the first heat exchanger.
4. The process according to any one of claims 2 to 3 wherein the second thermal exchange is performed after the first thermal exchange with respect to a flow of the lean LNG stream.
5. The process according to claim 2 wherein the first thermal exchange is performed after the second thermal exchange with respect to a flow of the lean LNG stream.

6. The process according to claim 5 wherein performing the second thermal exchange further occurs in a second heat exchanger between the lean LNG stream and the rich LNG feed, the second heat exchanger being distinct from the first heat exchanger, wherein the second thermal exchange is performed again after the first thermal exchange, and performing the second thermal exchange comprises feeding the rich LNG feed sequentially into the first heat exchanger and the second heat exchanger; and feeding the lean LNG stream sequentially into the second heat exchanger, the supplemental heat exchanger, and the first heat exchanger to allow the second thermal exchange to be performed again after the first thermal exchange.
7. The process according to claim 6 wherein separating NGL from the rich LNG feed occurs in a distillation column, the process further comprising diverting a portion of the rich LNG feed to the distillation column before the rich LNG feed enters the second heat exchanger.
8. The process according to any one of claims 2 to 7 further comprising compressing the lean LNG stream before performing the second thermal exchange.
9. The process according to claim 4 wherein separating NGL from the rich LNG feed occurs in a distillation column, the process further comprising separating a liquid residue from the lean LNG stream cooled from the first thermal exchange to provide a second lean LNG stream; compressing the second lean LNG stream before performing the second thermal exchange; and feeding the liquid residue back to the distillation column.
10. The process according to any one of claims 1 to 9 wherein the supplemental LNG feed is a lean LNG feed.
11. The process according to any one of claims 2 to 9 wherein the first and/or second thermal exchange reliquefies the lean LNG stream to provide a

reliquefied lean LNG suitable for storage in a liquefied LNG storage tank, and the reliquefied lean LNG has a temperature of -150 °C or lower.

5 12. The process according to claim 11 further comprising reducing a pressure of the reliquefied lean LNG.

13. The process according to any one of claims 1 to 12 wherein at least one of the following conditions are met:

- 10 (i) the process further comprising collecting the separated NGL;
- (ii) the process further comprising sending the supplemental LNG feed to a vaporiser for regasification after the first thermal exchange;
- (iii) the process further comprising pumping the rich LNG feed for the second thermal exchange using a booster pump;
- (iv) the separated NGL comprises alkanes with 2 or more carbon atoms.

15 14. A natural gas liquids (NGL) extraction apparatus configured to utilise cold energy recovered from a supplemental liquid natural gas (LNG) feed, the apparatus comprising

20 a distillation column configured to separate NGL from a rich LNG feed to provide a lean LNG stream and a NGL stream;

a supplemental heat exchanger configured to receive the lean LNG stream from the distillation column and to allow for a first thermal exchange between the lean LNG stream and the supplemental LNG feed, wherein the lean LNG stream is cooled thereby providing a cooled lean LNG stream and the supplemental LNG feed is heated, and wherein the supplemental heat exchanger is devoid of the rich LNG feed and is provided from a supplemental LNG storage tank, wherein the rich LNG feed is provided by a rich LNG storage tank.

30 15. The apparatus according to claim 14 further comprising a thermal exchange means configured to perform a second thermal exchange between the lean LNG stream and the rich LNG feed prior to the rich LNG feed entering the distillation column, wherein at the thermal exchange means the lean LNG

stream is cooled and the rich LNG feed is heated, the thermal exchange means comprising a first heat exchanger.

16. The apparatus according to claim 15 wherein the thermal exchange means comprises a second heat exchanger which is distinct from the first heat exchanger,

wherein the first heat exchanger and the second heat exchanger are configured and arranged to allow the rich LNG feed to be fed sequentially into the first heat exchanger and the second heat exchanger, and to allow the lean LNG stream to be fed sequentially into the second heat exchanger and the first heat exchanger, for the second thermal exchange to be performed.

17. The apparatus according to any one of claims 15 to 16 wherein the supplemental heat exchanger and thermal exchange means are arranged such that the second thermal exchange is performed after the first thermal exchange with respect to the flow of the lean LNG stream.

18. The apparatus according to claim 15 wherein the supplemental heat exchanger and thermal exchange means are arranged such that the first thermal exchange is performed after the second thermal exchange with respect to the flow of the lean LNG stream.

19. The apparatus according to claim 18 wherein the thermal exchange means comprises a second heat exchanger which is distinct from the first heat exchanger,

wherein the first heat exchanger and the second heat exchanger are configured and arranged to allow the rich LNG feed to be fed sequentially into the first heat exchanger and the second heat exchanger, and to allow the lean LNG stream to be fed sequentially into the second heat exchanger, the supplemental heat exchanger, and the first heat exchanger, to allow the second thermal exchange to be performed again after the first thermal exchange.

20. The apparatus according to claim 19 further comprising a flow path to allow a portion of the rich LNG feed to be diverted to the distillation column before the rich LNG feed enters the second heat exchanger.
- 5 21. The apparatus according to any one of claims 15 to 20 further comprising a compressor configured to compress the lean LNG stream before entering the thermal exchange means.
- 10 22. The apparatus according to claim 17 comprising a reflux drum and a compressor, the reflux drum configured to:
- (i) receive the cooled lean LNG stream from the supplemental heat exchanger;
 - (ii) separate a liquid residue from the cooled lean LNG stream to provide a second lean LNG stream;
 - 15 (iii) feeding the second lean LNG stream to the compressor;
 - (iv) feeding the liquid residue to the distillation column,
- wherein the compressor is configured to compress the second lean LNG stream before entering the thermal exchange means, and wherein the distillation column is configured to receive the liquid residue from the reflux drum.
- 20 23. The apparatus according to any one of claims 14 to 22 wherein the supplemental LNG feed is a lean LNG feed.
- 25 24. The apparatus of any one of embodiments 14 to 23, wherein the first and/or second thermal exchanger reliquefies the lean LNG stream to provide a reliquefied lean LNG, the apparatus comprising at least one of the following:
- (i) a storage tank to receive and store the reliquefied lean LNG;
 - (ii) a release valve configured to reduce the pressure of the reliquefied lean LNG before transfer to the storage tank;
 - 30 (iii) at least part of the re-liquefied lean LNG is used as the supplemental LNG feed;
 - (iv) a collection outlet in the distillation column to collect the separated NGL;

(v) a booster pump configured to transfer the rich LNG feed to the thermal exchange means.

- 5 25. A LNG terminal facility comprising the apparatus of any one of claims 14 to 24, the supplemental LNG storage tank configured to provide the supplemental LNG feed, and a vaporiser configured to regasify the supplemental LNG feed after the supplemental LNG feed is heated by the supplemental heat exchanger.