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(71) Applicant: **Air Products and Chemicals, Inc.**
Allentown, PA 18106-5500 (US)

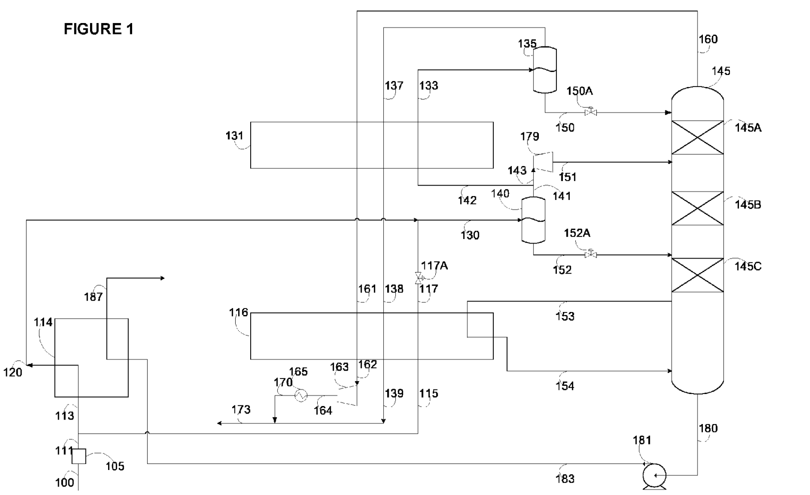
(72) Inventors:
- **ROBERTS, Mark Julian**
  Whitehall, 18052 (US)
- **CHEN, Fei**
  Whitehouse Station, 08889 (US)
- **SHNITSER, Russel B.**
  Coopersburg, 18036 (US)

(74) Representative: **Beck Greener LLP**
Fulwood House
12 Fulwood Place
London WC1V 6HR (GB)

(54) PRODUCING LNG FROM METHANE CONTAINING SYNTHETIC GAS

(57) Described herein are methods and systems for producing liquefied natural gas (LNG) from a methane-containing synthetic gas (MCSG). An MCSG feed stream may be cooled and partially liquefied using one or more heat exchanger units. A first phase separator and a second phase separator in downstream fluid flow communication with the first phase separator may be used to separate the partially liquefied MCSG stream into a first residue gas stream and first and second feed streams, the first and second feed streams then being fed into a distillation column to produce an LNG stream and a second residue gas stream.

FIGURE 1



EP 4 123 251 A2

Description

BACKGROUND

[0001] The present invention relates to a method and system for producing liquefied natural gas (LNG) from methane-containing synthetic gas (MCSG).

[0002] The evolution of environmentally friendly fuel technology has resulted in the integration of gasification and natural gas liquefaction process to produce LNG from MCSG. MCSG is a light hydrocarbon-containing gas comprising methane and impurities lighter than methane that can be produced from the gasification of coal or oil residues. Making MCSG from gasification products is a clean way of using traditionally solid and low-value heavy liquid fuels by allowing centralized carbon capture and sequestration while the clean low-carbon containing methane is produced and distributed. Additionally, co-production of LNG from a gasification process provides an attractive option to diversify a product portfolio, thus improving the overall economics of a project.

[0003] An exemplary prior art process for producing LNG from MCSG is depicted and described in US patent 10,436,505. In the process depicted therein, a hydrocarbon-containing feed gas stream, such as a syngas stream, is cooled to a relatively warm temperature of -30 to -130 °C in a main heat exchanger that utilizes a vaporizing mixed refrigerant to provide the refrigeration. The cooled feed gas stream exiting the main heat exchanger is further cooled in a reboiler which provides heat for boilup in a secondary distillation column (lower operating pressure). The cooled feed gas stream exiting the reboiler is then further cooled to a temperature -120 to -200 °C and at least partially liquefied in the main heat exchanger before being flashed and separated in a drum to form a flashed vapor stream and a liquid stream. The flashed vapor stream is expanded in the expander portion of a compander and routed to the rectification section of a primary distillation column (higher operating pressure). The liquid stream is let down in pressure via a valve and routed to the bottom of the primary distillation column.

[0004] A stream of bottoms liquid withdrawn from the primary distillation column is routed to the secondary distillation column to further improve methane recovery. A stream of bottoms liquid withdrawn from the secondary distillation column is cooled to a final temperature of - 120 to -200 °C in the main heat exchanger to form the LNG product stream. A stream of overhead vapor from the secondary distillation column is condensed in the main heat exchanger and flashed in reflux drum. The reflux drum liquid is used as reflux for both the primary and secondary distillation columns. The reflux drum vapor is compressed in the compression portion of the compander and is joined with the overhead vapour from the primary distillation column to form a stream of residue gas that is warmed in the main heat exchanger and recompressed in a residue gas compressor before being routed out of the facility.

[0005] A standard heat pump configuration using a two-stage compressor and a JT valve is used to provide cold refrigerant and hence refrigeration to the main heat exchanger.

[0006] The configuration shown in US patent 10,436,505 can produce high purity methane-rich LNG, but it does have certain disadvantages. One issue is that the mixed refrigerant stream is introduced into the main heat exchanger as a two-phase mixture. This complicates the design of the piping and may cause undesirable unsteady operation due to slugging. Also, two-phase flow requires special design features of the main heat exchanger to ensure that the liquid and vapor phases are evenly distributed. For example, if the main heat exchanger is a plate-fin exchanger, special devices such as a separator and injection tubes must be provided to evenly distribute the phases across all passages. The use of these devices adds cost and can reduce operation stability. Additionally, the two-phase flow may become unstable at low flowrates causing disengagement of the phases resulting in large internal temperature gradients and potential damage to the main heat exchanger.

[0007] Another disadvantage is that the main exchanger utilises two different low pressure streams for provide cooling duty to the heat exchanger (i.e. the cold vaporizing mixed refrigerant stream and the residue gas stream), which practically precludes the use of a coil-wound type heat exchanger as the main heat exchanger. Coil-wound heat exchangers are proven to be efficient, reliable, and robust for natural gas liquefaction and end flash gas heat exchange applications. The design and manufacturing technology of coil-wound heat exchangers allows much higher unit processing capacity (heat exchange duty achieved per coil-wound heat exchanger unit), avoiding using multiple heat exchanger units (in the case of plate fine heat exchanger) in parallel up to very large capacities. A coil-wound heat exchanger unit comprises one or more tube bundles encased in a shell casing, the tube side of the unit being designed to receive one or more hot streams that require cooling, and the shell side of the unit being designed to receive a single stream of cold refrigerant or two or more cold streams that mix in the shell side and exit as a single stream of warmed refrigerant. The only way that a coil-wound heat exchanger could accommodate the use of two or more cold streams that are to be kept separate would be to pass at least one of the cold streams through one of the passages on the tube side of the heat exchanger. However, the design of the coil-wound exchanger would then be difficult given the low available pressure drop and the relatively high typical resistance in the passages on the tube side of the heat exchanger.

[0008] A further disadvantage of the depicted process is that all of the residue gas is produced at a relatively low pressure. This increases the operating and capital costs of the process, as the larger the amount of residue gas produced at low pressure the greater the power requirement for recompressing said gas and the larger the residue gas compressor has to be to accommodate said gas.

BRIEF SUMMARY

[0009] Disclosed herein are methods and systems for producing LNG from MCSG that provide several advantages over the prior art described above. The methods and systems may employ a single distillation column (instead of two or more columns). A coil-wound heat exchanger unit may be used that is separate from the heat exchanger unit(s) used to recover refrigeration from the residue gas streams, which coil-wound heat exchanger unit may receive, cool, and partially liquefy a portion of the MCSG feed stream, and/or which may receive and cool the refrigerant (such as a mixed refrigerant or other vaporizing refrigerant) that is then used for cooling and partially liquefying the MCSG feed stream. A portion of the residue gas may be rejected at substantially the same pressure as the MCSG feed stream and require relatively little or no recompression.

[0010] Several preferred aspects of the systems and methods according to the present invention are outlined below.

[0011] Aspect 1: A method for producing liquefied natural gas (LNG) from methane containing synthetic gas (MCSG), the method comprising:

(a) cooling and partially liquefying a MCSG feed stream to produce a partially liquefied MCSG feed stream;
(b) using a first phase separator and a second phase separator arranged in series, with the second phase separator being in downstream fluid flow communication with the first phase separator, to separate the partially liquefied MCSG feed stream into at least three streams comprising a liquid stream and two vapor streams, the liquid stream forming a first feed stream, one of the vapor streams forming a second feed stream, and the other of the vapor streams forming a first residue gas stream;
(c) introducing the first feed stream into a distillation column at a first location;
(d) introducing the second feed stream into the distillation column at a second location that is above the first location, there being at least one separation stage between the first location and second location;
(e) withdrawing an LNG stream from the distillation column comprising distillation column bottoms liquid; and
(f) withdrawing a second residue gas stream from the distillation column comprising distillation column overhead vapor.

[0012] Aspect 2: The method of Aspect 1, wherein step (b) comprises:

(i) separating the partially liquefied MCSG feed stream in the first phase separator into the liquid stream that forms the first feed stream, and a vapor stream;
(ii) dividing the vapor stream from the first phase separator to form the vapor stream that forms the second feed stream, and a vapor stream that forms a third feed stream; and
(iii) cooling and partially liquefying the third feed stream and then separating the third feed stream in the second phase separator into the vapor stream

that forms the first residue gas stream, and a liquid stream that forms a fourth feed stream;
wherein step (c) comprises reducing the pressure of the first feed stream and then introducing the first feed stream into a distillation column at the first location;
wherein step (d) comprises reducing the pressure of the second feed stream and then introducing the second feed stream into the distillation column at the second location; and
wherein the method further comprises reducing the pressure of the fourth feed stream and then introducing the fourth feed stream into the distillation column at a third location that is above the second location, there being at least one separation stage between the second location and third location.

[0013] Aspect 3: The method of Aspect 2, wherein the third location is at the top of the distillation column.

[0014] Aspect 4: The method of Aspect 2 or 3, wherein one or both of the first residue gas stream and the second residue gas stream are warmed via indirect heat exchange with the third feed stream in order to provide cooling duty for the cooling and partial liquefaction of the third feed stream in step (b)(iii).

[0015] Aspect 5: The method of Aspect 1, wherein step (b) comprises:

(i) separating the partially liquefied MCSG stream in the first phase separator into the vapor stream that forms the first residue gas stream, and a liquid stream that forms a third feed stream; and
(ii) reducing the pressure of and partially vaporizing the third feed stream and separating said stream in the second phase separator into the liquid stream that forms the first feed stream and the vapor stream that forms the second

feed stream; and

wherein step (c) comprises warming the first feed stream and then introducing the first feed stream into a distillation column at the first location.

[0016] Aspect 6: The method of Aspect 5, wherein there is at least one separation stage between the second location and the top of the column, and the method further comprises: compressing, cooling, expanding, and thereby at least partially liquefying a portion of the second residue gas stream or distillation column overhead vapor to form a reflux stream; and introducing the reflux stream into the distillation column at a third location that is at the top of the distillation column.

[0017] Aspect 7: The method of Aspect 5 or 6, wherein in step (c) the first feed stream is warmed via indirect heat exchange with the MCSG feed stream in order to provide cooling duty for the cooling and partial liquefaction of the MCSG feed stream in step (a).

[0018] Aspect 8: The method of any one of Aspects 1 to 7, wherein one or both of the first residue gas stream and the second residue gas stream are warmed via indirect heat exchange with the MCSG feed stream in order to provide cooling duty for the cooling and partial liquefaction of the MCSG feed stream in step (a).

[0019] Aspect 9: The method of any one of Aspects 1 to 8, wherein there is at least one separation stage between the first location and the bottom of the column, and wherein the method further comprises warming and thereby at least partially vaporizing a portion of the LNG stream or distillation column bottoms liquid to form a boil-up stream, and introducing the boil-up stream into the distillation column at the bottom of the distillation column.

[0020] Aspect 10: The method of any one of Aspects 1 to 9, wherein at least a portion of the second residue gas stream is compressed and combined with first residue gas stream.

[0021] Aspect 11: The method of any one of Aspects 1 to 10, wherein the method further comprises subcooling the LNG stream.

[0022] Aspect 12: The method of any one of Aspects 1 to 11, wherein step (a) comprises:

(i) dividing the MCSG feed stream into at least two portions, comprising a first portion and a second portion;
(ii) cooling and partially liquefying the first portion of the MCSG feed stream in a first heat exchanger unit or set of units via indirect heat exchange with a first refrigerant, wherein the first heat exchanger unit or set of units is a coil-wound heat exchanger unit or set of units;
(iii) cooling and partially liquefying the second portion of the MCSG feed stream in a second heat exchanger unit or set of units via indirect heat exchange with one or more process streams; and
(iv) combining the cooled and partially liquefied first portion and the cooled and partially liquefied second portion to form the partially liquefied MCSG feed stream.

[0023] Aspect 13: The method of Aspect 12, wherein the second heat exchanger unit or set of units is a plate fin heat exchanger unit or set of units.

[0024] Aspect 14: The method of Aspects 12 or 13, wherein in step (a)(iii) the one or more process streams comprise one or more streams selected from the first residue gas stream, the second residue gas stream, and a portion of the LNG stream or distillation column bottoms liquid.

[0025] Aspect 15: The method of any one of Aspects 12 to 14, wherein the first refrigerant is a refrigerant that vaporizes as it is warmed in the first heat exchanger unit or set of units.

[0026] Aspect 16: The method of any one of Aspects 12 to 15, wherein the method further comprises subcooling the LNG stream in the first heat exchanger unit or set of units via indirect heat exchange with the first refrigerant.

[0027] Aspect 17: The method of any one of Aspects 12 to 16, wherein step (a)(ii) comprises cooling and partially liquefying the first portion of the MCSG feed stream in the first heat exchanger unit or set of units via indirect heat exchange with one or more streams of cooled first refrigerant, wherein the first heat exchanger unit or set of units is a coil-wound heat exchanger unit or set of units, and wherein the one or more streams of cooled first refrigerant are produced by also cooling the first refrigerant in the first heat exchanger unit or set of units.

[0028] Aspect 18: The method of any one of Aspects 1 to 11, wherein step (a) comprises:

(i) cooling a first refrigerant in a first heat exchanger unit or set of units to produce a cooled first refrigerant, wherein the first heat exchanger unit or set of units is a coil-wound heat exchanger unit or set of units;
(ii) cooling and partially liquefying the MCSG feed stream in a second heat exchanger unit or set of units, via indirect heat exchange with one or more streams of the cooled first refrigerant and one or more process streams, to form the partially liquefied MCSG feed stream.

[0029] Aspect 19: The method of Aspect 18, wherein the second heat exchanger unit or set of units is a plate fin heat exchanger unit or set of units.

[0030] Aspect 20: The method of Aspect 18 or 19, wherein in step (a)(ii) the one or more process streams comprise one or more of the first residue gas stream, the second residue gas stream, and a portion of the LNG stream or distillation column bottoms liquid.

[0031] Aspect 21: The method of any one of Aspects 18 to 20, wherein in step (a)(i) the first refrigerant is cooled in the first heat exchanger unit or set of units via indirect heat exchange with a portion of the cooled first refrigerant that is produced in step (a)(i).

[0032] Aspect 22: The method of any one of Aspects 18 to 21, wherein the method further comprises subcooling the LNG stream in the first heat exchanger unit or set of units.

[0033] Aspect 23: A method for producing liquefied natural gas (LNG) from methane containing synthetic gas (MCSG), the method comprising:

(a) cooling and partially liquefying a MCSG feed stream to produce a partially liquefied MCSG feed stream by:

(i) dividing the MCSG feed stream into at least two portions, comprising a first portion and a second portion;
(ii) cooling and partially liquefying the first portion in a first heat exchanger unit or set of units via indirect heat exchange with a first refrigerant, wherein the first heat exchanger unit or set of units is a coil-wound heat exchanger unit or set of units;
(iii) cooling and partially liquefying the second portion in a second heat exchanger unit or set of units via indirect heat exchange with one or more process streams; and
(iv) combining the cooled and partially liquefied first portion and the cooled and partially liquefied second portion to form the partially liquefied MCSG feed stream;

(b) separating the partially liquefied MCSG feed stream into a LNG stream and one or more residue gas streams.

[0034] Aspect 24: The method of Aspect 23, wherein in step (b) the partially liquefied MCSG feed stream is separated into the LNG stream and the one or more residue gas streams using one or more phase separators and/or one or more distillation columns.

[0035] Aspect 25: The method of Aspect 23 or 24, wherein the second heat exchanger unit or set of units is a plate fin heat exchanger unit or set of units.

[0036] Aspect 26: The method of any one of Aspects 23 to 25, wherein in step (a)(iii) the one or more process streams comprise one or more streams selected from the one or more of the residue gas streams, a portion of the LNG stream, or a portion of a distillation column bottoms liquid.

[0037] Aspect 27: The method of any one of Aspects 23 to 26, wherein the first refrigerant is a refrigerant that vaporizes as it is warmed in the first heat exchanger unit or set of units.

[0038] Aspect 28: The method of any one of Aspects 23 to 27, wherein the method further comprises subcooling the LNG stream in the first heat exchanger unit or set of units via indirect heat exchange with the first refrigerant.

[0039] Aspect 29: The method of any one of Aspects 23 to 28, wherein step (a)(ii) comprises cooling and partially liquefying the first portion of the MCSG feed stream in the first heat exchanger unit or set of units via indirect heat exchange with one or more streams of cooled first refrigerant, wherein the first heat exchanger unit or set of units is a coil-wound heat exchanger unit or set of units, and wherein the one or more streams of cooled first refrigerant are produced by also cooling the first refrigerant in the first heat exchanger unit or set of units.

[0040] Aspect 30: A method for producing liquefied natural gas (LNG) from methane containing synthetic gas (MCSG), the method comprising:

(a) cooling and partially liquefying a MCSG feed stream to produce a partially liquefied MCSG feed stream by:

(i) cooling a first refrigerant in a first heat exchanger unit or set of units to produce a cooled first refrigerant, wherein the first heat exchanger unit or set of units is a coil-wound heat exchanger unit or set of units;
(ii) cooling and partially liquefying the MCSG feed stream in a second heat exchanger unit or set of units, via indirect heat exchange with one or more streams of the cooled first refrigerant and one or more process streams, to form the partially liquefied MCSG feed stream;

(b) separating the partially liquefied MCSG feed stream into a LNG stream and one or more residue gas streams.

[0041] Aspect 31: The method of Aspect 30, wherein in step (b) the partially liquefied MCSG feed stream is separated into the LNG stream and the one or more residue gas streams using one or more phase separators and/or one or more distillation columns.

[0042] Aspect 32: The method of Aspect 30 or 31, wherein the second heat exchanger unit or set of units is a plate fin heat exchanger unit or set of units.

[0043] Aspect 33: The method of any one of Aspects 30 to 32, wherein in step (a)(ii) the one or more process streams comprise one or more of the first residue gas stream, the second residue gas stream, and a portion of the LNG stream or distillation column bottoms liquid.

[0044] Aspect 34: The method of any one of Aspects 30 to 33, wherein in step (a)(i) the first refrigerant is cooled in the first heat exchanger unit or set of units via indirect heat exchange with a portion of the cooled first refrigerant that is produced in step (a)(i).

[0045] Aspect 35: The method of any one of Aspects 30 to 34, wherein the method further comprises subcooling the LNG stream in the first heat exchanger unit or set of units.

[0046] Aspect 36: A system for producing liquefied natural gas (LNG) from methane containing synthetic gas (MCSG), the system comprising:

one or more heat exchanger units for receiving, cooling and partially liquefying a MCSG feed stream to produce a partially liquefied MCSG feed stream;
a first phase separator and a second phase separator in fluid flow communication with the one or more heat exchanger units and arranged in series, with the second phase separator being in downstream fluid flow communication with the first phase separator, for separating the partially liquefied MCSG feed stream into at least three streams comprising a liquid stream and two vapor streams, the liquid stream forming a first feed stream, one of the vapor streams forming a second feed stream, and the other of the vapor streams forming a first residue gas stream; and
a distillation column having: a first inlet at a first location for receiving the first feed stream; a second inlet at second location for receiving the second feed stream, the second location being above the first location and having at least one separation stage between the first location and second location; an outlet at the bottom of the distillation column for withdrawal of an LNG stream formed of distillation column bottoms liquid; and an outlet at the top of the distillation column for withdrawal of a second residue gas stream formed of distillation column overhead vapor.

[0047] Aspect 37: A system for producing liquefied natural gas (LNG) from methane containing synthetic gas (MCSG), the system comprising:

a set of conduits for dividing a MCSG feed stream into at least two portions, comprising a first portion and a second portion;
a first heat exchanger unit or set of units for receiving the first portion and cooling and partially liquefying the first portion via indirect heat exchange with a first refrigerant, wherein the first heat exchanger unit or set of units is a coil-wound heat exchanger unit or set of units;
a second heat exchanger unit or set of units for receiving the second portion and cooling and partially liquefying the second portion via indirect heat exchange with one or more process streams;
a set of conduits for receiving and combining the cooled and partially liquefied first portion and the cooled and partially liquefied second portion to form a partially liquefied MCSG feed stream; and
one or more phase separators and/or one or more distillation columns for receiving and separating the partially liquefied MCSG feed stream into a LNG stream and one or more residue gas streams.

[0048] Aspect 38: A system for producing liquefied natural gas (LNG) from methane containing synthetic gas (MCSG), the system comprising:

a first heat exchanger unit or set of units for cooling a first refrigerant to produce a cooled first refrigerant, wherein the first heat exchanger unit or set of units is a coil-wound heat exchanger unit or set of units;
a second heat exchanger unit or set of units for receiving one or more streams of the cooled first refrigerant from the first heat exchanger unit, for receiving one or more process streams, and for receiving an MCSG feed stream and cooling and partially liquefying the MCSG feed stream to form a partially liquefied MCSG feed stream via indirect heat exchange with the one or more streams of the cooled first refrigerant and the one or more process streams; and
one or more phase separators and/or one or more distillation columns for receiving and separating the partially liquefied MCSG feed stream into a LNG stream and one or more residue gas streams.

BRIEF DESCRIPTION OF THE DRAWINGS

[0049]

Figure 1 is a schematic flow diagram depicting a method and system for producing LNG from MCSG according to one embodiment of the invention.

Figure 1A is a schematic flow diagram depicting a refrigeration system suitable for use in the method and system of Figure 1.

Figure 2 is a schematic flow diagram depicting a method and system for producing LNG from MCSG according to another embodiment of the invention.

Figure 3 is a schematic flow diagram depicting a method and system for producing LNG from MCSG according to another embodiment of the invention.

Figure 3A is a schematic flow diagram depicting a refrigeration system suitable for use in the method and system of Figure 3.

Figure 4 is a schematic flow diagram depicting a method and system for producing LNG from MCSG according to another embodiment of the invention.

DETAILED DESCRIPTION

[0050] Described herein are methods and systems for producing LNG from MCSG.

[0051] As used herein and unless otherwise indicated, the articles "a" and "an" mean one or more when applied to any feature in embodiments of the present invention described in the specification and claims. The use of "a" and "an" does not limit the meaning to a single feature unless such a limit is specifically stated. The article "the" preceding singular or plural nouns or noun phrases denotes a particular specified feature or particular specified features and may have a singular or plural connotation depending upon the context in which it is used.

[0052] Where letters are used herein to identify recited steps of a method (e.g. (a), (b), and (c)), these letters are used solely to aid in referring to the method steps and are not intended to indicate a specific order in which claimed steps are performed, unless and only to the extent that such order is specifically recited.

[0053] Where used herein to identify recited features of a method or system, the terms "first", "second", "third" and so on, are used solely to aid in referring to and distinguishing between the features in question, and are not intended to indicate any specific order of the features, unless and only to the extent that such order is specifically recited.

[0054] As used herein, the term "methane containing synthetic gas", also referred to herein as "MCSG", refers to a gas comprising methane and components lighter than methane (i.e. components having a higher volatility and lower boiling point than methane) such as in particular hydrogen and/or carbon monoxide. The term as used herein includes gasification syngas product streams containing methane molecules and synthetic natural gas streams produced from methanation process which contain impurities such as hydrogen and carbon monoxide. In preferred embodiments, a methane-containing synthetic gas feed stream may comprise 10-60 mol% methane with the remaining content being a mixture of carbon monoxide and hydrogen, optionally with a small amounts of carbon dioxide, water, and/or other impurities.

[0055] As used herein, the term residue gas refers to a gas comprising predominantly components lighter than methane removed from the MCSG feed stream, such as in particular hydrogen and/or carbon monoxide. In preferred embodiments, a residue gas stream may comprise less than 10 mol% methane, and more preferably less than 2 mol% methane, with the remainder consisting or consisting essentially of components lighter than methane, such as for example a mixture of hydrogen and carbon monoxide, optionally with small amounts of other components such as nitrogen and/or argon.

[0056] As used herein, the term "liquefied natural gas" or "LNG" refers to a liquefied gas stream comprising predominantly methane, which preferably comprises at least 85 mole%, more preferably at least 90 mole%, and most preferably at least about 95 mole% of the feed stream. An LNG stream may still contain small amounts of other components as may have been present in the MCSG feed stream and have not been removed by the process, such as small amounts of other components heavier (i.e. lower volatility and higher boiling point) than methane, such as carbon dioxide or hydrocarbons heavier than methane (e.g. ethane, propane, butane, pentanes) and/or small amounts of components lighter than methane, such as nitrogen, hydrogen or carbon monoxide.

[0057] As used herein, the term "distillation column" refers to a column containing one or more separation stages, composed of devices such as packing or trays, that increase contact and thus enhance mass transfer between upward rising vapor and downward flowing liquid flowing inside the column. In this way, the concentration of lighter (i.e. higher volatility and lower boiling point) components increases in the rising vapor that collects as overhead vapor at the top of the column, and the concentration of heavier (i.e. lower volatility and higher boiling point) components increases in the descending liquid that collects as bottoms liquid at the bottom of the column. The "top" of the distillation column refers to the part of the column at or above the top-most separation stage. The "bottom" of the column refers to the part of the column at or below the bottom-most separation stage. An "intermediate location" of the column refers to a location between the top and bottom of the column, between two separation stages.

[0058] As used herein, the term "phase separator" refers to a drum or other form of vessel in which a two phase stream can be introduced in order to separate the stream into its constituent vapor and liquid phases where the liquid and vapor streams exiting the vessel are in equilibrium. In contrast to a distillation column (in which the liquid and vapor streams exiting the column are not in equilibrium), a phase separator does not contain any separation stages (i.e. packing or trays) inside the vessel for bringing upward rising vapor and downward flowing liquid into contact.

[0059] As used herein, the term "fluid flow communication" refers to the nature of connectivity between two or more components that enables liquids, vapors, and/or two-phase mixtures to be transported between the components in a controlled fashion (i.e., without leakage) either directly or indirectly. Coupling two or more components such that they are in fluid flow communication with each other can involve any suitable method known in the art, such as with the use of welds, flanged conduits, gaskets, and bolts. Two or more components may also be coupled together via other components of the system that may separate them, for example, valves, gates, or other devices that may selectively restrict or direct fluid flow.

[0060] Reference herein to a second device or component being in "downstream" fluid flow communication with a first device or component means that said second device or component is arranged so as to receive fluid, either directly or indirectly, from said first device or component.

[0061] As used herein, the term "indirect heat exchange" refers to heat exchange between two fluids where the two fluids are kept separate from each other by some form of physical barrier.

[0062] As used herein, the term "coil-wound heat exchanger unit" refers to a heat exchanger unit of the type known in the art, comprising one or more tube bundles encased in a shell casing. Each tube bundle comprises a plurality of tubes, the interior of the tubes defining one or more passages (also referred to as tube circuits) for passing one or more fluid streams through the heat exchanger unit, the interior of said tubes being referred to herein as the "tube side" of the heat exchanger unit. The space internal to the shell casing and external to the tubes defines a single passage for passing a fluid stream through the heat exchanger unit, said space internal to the shell casing and external to the tubes being referred to herein as the "shell side" of the heat exchanger unit. In this way, a fluid passing through the shell side of the heat exchanger can undergo indirect heat exchange with a fluid passing through the tube side of the heat exchanger. Where the coil-wound heat exchanger unit is being used to cool one or more 'hot' fluid streams via indirect heat exchange with a 'cold' refrigerant, the cold refrigerant is almost always passed through the shell side of the heat exchanger, as the shell side provides much lower flow resistance and allows for a much greater pressure drop than the tube side, which makes passing the cold refrigerant through the shell side much more effective and efficient (the cold refrigerant typically being a vaporizing or expanding fluid at a relatively low pressure). Coil wound heat exchangers are a compact design of heat exchanger known for their robustness, safety, and heat transfer efficiency, and thus have the benefit of providing highly efficient levels of heat exchange relative to their footprint. However, because the shell side defines only a single passage through the heat exchanger, it is not practicable use more than one stream of cold refrigerant to provide cooling duty in a coil-wound heat exchanger if the mixing of said streams of refrigerant is not permitted.

[0063] Solely by way of example, various exemplary embodiments of the invention will now be described with reference to the Figures.

[0064] Referring now to Figure 1, a method and system for producing LNG from MCSG in accordance with a first embodiment of the invention is shown.

[0065] An MCSG feed stream 100, such as for example a syngas stream 100 comprising a mixture of hydrogen, carbon monoxide, carbon dioxide, nitrogen, water, methane, ethane and other hydrocarbons, which is at ambient temperature and a high-pressure, typically 20 to 80 bara, may first be routed to a pretreatment system 105. Depending on the composition of the MCSG feed stream, the pretreatment system can include an acid gas removal unit for removing hydrogen sulphide and carbon dioxide impurities, a dehydration unit for removing water, and a mercury removal unit for removing mercury. There may also be a heavy component removal step in which LPG (liquified petroleum gas) components, freezable pentane and heavier components, are removed. As such, the flowrate and composition of the MCSG feed stream 111 exiting the pretreatment section 105 may be significantly different than that of the MCSG feed stream 100 entering said pretreatment section 105, although the MCSG feed stream will still comprise methane and components lighter than methane, in particular hydrogen and carbon monoxide.

[0066] The MCSG feed stream 111 exiting the pretreatment section 105, which is typically at ambient temperature, is then divided into two streams, namely a first stream 113 and a second stream 115. The first stream 113, which preferably consists of a minor portion of the MCSG feed stream 111, such as between 10 and 40 percent and more preferably between 20 and 30 percent of the flow of the MCSG feed stream 111, is sent to a first heat exchanger unit or set of units 114. The second stream 115, which consists of the remainder of the flow of the MCSG feed stream 111 and hence preferably consists of a major portion of said stream, is sent to a second heat exchanger unit or set of units 116. The second heat exchanger unit or set of units 116 may for example comprise a plate fin exchanger unit or a plurality of plate fin exchanger units arranged in parallel. The first and second streams 113 and 115 are cooled and partially liquefied in, respectively, the first heat exchanger unit(s) 114 and second heat exchanger unit(s) 116, forming respectively a first cooled and partially liquefied stream 120 and a second cooled and partially liquefied stream 117 that are each at a temperature of between -130°C and -160°C and more preferably between -140°C and -150°C. The first and second cooled and partially liquefied streams 120, 117 are then combined (with the pressure of the second cooled and partially liquefied stream 117 first being regulated, if necessary, and via for example a pressure regulator valve 117A, to control the flow of said stream 117) to form a partially liquefied MCSG feed stream 130 that is then separated using a first phase separator 140 and a second phase separator 135 arranged in series, with the second phase separator being in downstream fluid flow communication with the first phase separator.

[0067] More specifically, the partially liquefied MCSG feed stream 130 is first introduced into the first phase separator 140 which in this case is a flash drum in which the partially liquefied MCSG feed stream is flashed and separated into a liquid steam that forms a first feed stream 152, and a vapor stream 141. The vapor stream 141 is divided to form a second feed stream 143 (which preferably consists of between 60 and 90 percent or more preferably between 70 and 80 percent of the flow of vapor stream 141) and a third feed stream 142 (which consists of the remainder of vapor stream 141, i.e. preferably between 10 and 40 percent and more preferably between 20 and 30 percent of the flow of said stream). The third feed stream 142 is further cooled and partially liquefied to form a partially liquefied third feed stream 133 at a temperature of between -170°C and -200°C and more preferably between -180°C and -190°C. The partially liquefied third feed stream 133 is then introduced into the second phase separator 135 which in this case is a flash drum in which the partially liquefied third feed stream is flashed and separated into a liquid stream that forms a fourth feed stream 150 and a vapor stream that forms a first residue gas stream 137.

[0068] The third feed stream 142 may be further cooled and partially liquefied to form the partially liquefied third feed stream 133 by passing the third feed stream 142 through a third heat exchanger unit or set of units 131 as shown in Figure 1, which unit(s) may for example comprise a plate fin exchanger unit or a plurality of plate fin exchanger units arranged in parallel. Alternatively, the third heat exchanger unit(s) may be combined with the second heat exchanger unit(s) into a single unit, or set of units in parallel, with stream 115 being cooled in a warmer section of said unit(s) and stream 142 being cooled in a colder section of said unit(s).

[0069] The first feed stream 152 and fourth feed stream 150 are reduced in pressure, for example by passing stream 152 through J-T valve 152A and stream 150 through J-T valve 150A, after which each of said streams will be two-phase. The second feed stream 143 is reduced in pressure, for example by expanding the stream in an expander 179, after which said second feed stream 151 may be vapor or two-phase. The expansion work from expander 179 may for example be recovered by coupling the expander to a compressor which compresses feed or residue gas, or may for example be recovered in a generator. The first feed stream 152, second feed stream 151 and fourth feed stream 150 are then each introduced into different locations of a distillation column 145, as will be further described below, which distillation column 145 operates at a pressure of between 1.0 and 5.0 bara, and more preferably between 1.5 and 3.5 bara.

[0070] The first feed stream 152 is introduced into the distillation column 145 at a first location that is above one or more separation stages of the column that are represented in Figure 1 by section 145C of the column, and that is below one or more separation stages of the column that are represented in Figure 1 by section 145B of the column. The second feed stream 151 is introduced into the distillation column at a second location that is above the one or more separation stages of the column that are represented by section 145B, and that is below one or more separation stages of the column that are represented in Figure 1 by section 145A of the column. The fourth feed stream 150 is introduced into the distillation column at a third location that is at the top of the column, above the one or more separation stages of the column that are represented by section 145A, thereby providing a source of reflux to the column.

[0071] Reboiler duty for the distillation column 145 is provided warming and thereby at least partially vaporizing a stream of distillation column bottoms liquid 153 in the second heat exchanger unit or set of units 116, via indirect heat exchange with the second stream 115 (obtained from dividing the MCSG feed stream), thereby forming a boil-up stream 154 (formed of said partially vaporized distillation column bottoms liquid) that is reintroduced into the bottom of the distillation column.

[0072] An LNG stream 180 formed of distillation column bottoms liquid is withdrawn from the bottom of the distillation column 145 at a temperature between -130°C and -160°C, and more preferably between -140°C and -150°C, and is preferably increased in pressure in pump 181 and sent (as stream 183) to and passed through the first heat exchanger unit or set of units 114 to be subcooled to form a subcooled LNG product stream 187 that can be stored in a LNG storage vessel on-site or transferred directly off-site (for example via a pipeline or a transport vessel). The LNG stream 180, 187 typically contains 1 mole % or less nitrogen, preferably less than 0.5 mole %, and preferably also has a carbon monoxide content of 10 ppm or less. The percent of methane recovered in the LNG stream 180, 187 from the MCSG feed stream 111 can be higher than 95%.

[0073] A second residue gas stream 160 formed of distillation column overhead vapor is withdrawn from the top of the distillation column 145 at a temperature between -170°C and - 200°C, and more preferably between -180°C and -190°C, and typically contains greater than 95 and preferably greater than 98 mole % hydrogen and carbon monoxide.

[0074] The first residue gas stream 137 and second residue gas stream 160 are each passed through and warmed in the third heat exchanger unit or set of units 131, via indirect heat exchange with the third feed stream 142, and are then each (c.f. streams 138 and 161) passed through and further warmed in the second heat exchanger unit or set of units 116, via indirect heat exchange with the second stream 115 obtained from dividing the MCSG feed stream (or in the alternative embodiment where the third heat exchanger unit(s) are combined with the second heat exchanger unit(s), the first residue gas stream 137 and second residue gas stream 160 are warmed in the colder section of said combined unit(s) and then further warmed in the warmer section of said combined unit(s)). The resulting warmed second residue gas stream 162 is then compressed and cooled in a compressor 163 and aftercooler 165 before being mixed with the resulting warmed first residue gas stream 139 to formed a combined residue gas stream 173. The residue gas stream 173 may be used for fuel for the plant or sent to downstream units for further purification, separation, and/or chemical synthesis. Optionally, some or all of stream 139 may be purified to make a hydrogen product and not combined with stream with residue gas stream 170.

[0075] The first heat exchanger unit or set of units 114 is a preferably coil-wound unit or set of units, as for example shown in Figure 1A. Any type of refrigeration process as known in the art for the liquefaction of natural gas (including synthetic or substitute natural gases) may be employed in the first heat exchanger unit or set of units 114, such as a single mixed refrigerant process; dual mixed refrigerant process; propane, ammonia or HFC pre-cooled mixed refrigerant process; reverse Brayton cycle using nitrogen, methane or ethane; or multiple fluid cascade cycle. However, in an exemplary embodiment a SMR (single mixed refrigerant) process may be used, such as the one depicted in Figure 1A.

[0076] As shown in Figure 1A, the coil-wound heat exchanger unit 114 comprises a warm section comprising a warm tube bundle 114A and cold section comprising a cold tube bundle 114B (the terms warm and cold being relative). The first stream 113 obtained from dividing the MCSG feed stream is passed through and cooled and partially liquefied in the warm tube bundle 114A to form the first cooled and partially liquefied stream 120. The LNG steam 183 is passed through and subcooled in the cold tube bundle 114B to form the subcooled LNG product stream 187. Cooling duty is supplied to the warm and cold tube bundles of the coil-wound heat exchanger unit by vaporizing mixed refrigerant passing through the shell side of the heat exchanger unit. The SMR cycle depicted in Figure 1A that is used to supply vaporizing cold mixed refrigerant to the shell side of the heat exchanger unit is one that is well known in the art, and so for the sake of brevity will only cursorily be described here. Very briefly, warmed vaporized mixed refrigerant withdrawn from the shell side at the bottom of the heat exchanger unit is compressed, cooled and separated, in a compression train comprising one or more compressor stages 115A, 115B, aftercoolers and phase separators, into one or more MRL (mixed refrigerant liquid) streams, two being shown in the figure, and one or more MRV (mixed refrigerant vapor) streams, one being shown in the figure. The MRL streams are passed through and cooled in the warm tube bundle, expanded through J-T valves and combined and introduced into the shell side of the heat exchanger unit at the top of the warm bundle to provide vaporizing refrigerant flowing downwards through the shell side around the tubes of the warm tube bundle. The MRV stream is passed through and cooled and at least partially liquefied in the warm and cold tube bundles, expanded though a J-T valve and introduced into the shell side of the heat exchange unit at the top of the cold bundle to provide vaporizing refrigerant flowing downwards through the shell side around the tubes of the cold and warm tube bundles.

[0077] The method and system of Figure 1 produces a high purity methane-rich LNG product with a high methane recovery. It requires only a single distillation column and recompression of only part of the residue gas that is produced (i.e. only the residue gas contained in the second residue gas stream), hence reducing the capital and operating costs and footprint of the system as compared to systems requiring multiple distillation columns, recompression of all of the residue gas produced, and a compressor capable of compressing all of the residue gas produced. It allows use of a coil-wound heat exchanger unit, thereby also taking advantage of the benefits provided by such units in terms of their compact design, robustness, safety, and heat transfer efficiency, further reducing the footprint and enhancing the efficiency of the system and process. It also avoids use of a two-phase refrigerant in the second and third heat exchanger units, which as discussed may for example be plate fin exchanger units, thereby avoiding any operational difficulties that may result from use of such a refrigerant in such types of heat exchanger.

[0078] Figure 2 shows a method and system for producing LNG from MCSG in accordance with a second embodiment of the invention. The embodiment depicted in Figure 2 differs from that shown in Figure 1 as regards the manner in which partially liquefied MCSG feed stream is separated by the first and second phase separators, and as regards the manner in which reflux is provided to the distillation column.

[0079] An MCSG feed stream 200, such as for example a syngas stream 200 comprising a mixture of hydrogen, carbon monoxide, carbon dioxide, nitrogen, water, methane, ethane and other hydrocarbons, which is at ambient temperature and a high-pressure, typically 20 to 80 bara, may first be routed to a pretreatment system 205. Depending on the composition of the MCSG feed stream, the pretreatment system can include an Acid Gas Removal Unit for removing hydrogen sulphide and carbon dioxide impurities, a Dehydration Unit for removing water, and a Mercury Removal Unit for removing mercury. There may also be a heavy component removal step in which LPG (liquified petroleum gas) components, freezable pentane and heavier components, are removed. As such, the flowrate and composition of the MCSG feed stream 211 exiting the pretreatment section 205 may be significantly different than that of the MCSG feed stream 200 entering said pretreatment section 205, although the MCSG feed stream will still comprise methane and components lighter than methane, in particular hydrogen and carbon monoxide.

[0080] The MCSG feed stream 211 exiting the pretreatment section 205, which is typically at ambient temperature, is then divided into two streams, namely a first stream 213 and a second stream 215. The first stream 213, which preferably consists of a minor portion of the MCSG feed stream 211, such as between 10 and 40 percent and more preferably between 20 and 30 percent of the flow of the MCSG feed stream 211, is sent to a first heat exchanger unit or set of units 214. The second stream 215, which consists of the remainder of the flow of the MCSG feed stream 211 and hence preferably consists of a major portion of said stream, is sent to a second heat exchanger unit or set of units 216. The second heat exchanger unit or set of units 216 may for example comprise a plate fin exchanger unit or a plurality of plate fin exchanger units arranged in parallel. The first and second streams 213 and 215 are cooled and partially liquefied in, respectively, the first heat exchanger unit(s) 214 and second heat exchanger unit(s) 216, forming respectively a first cooled and partially liquefied stream 220 and a second cooled and partially liquefied stream 217 that are each at a temperature of between -120°C and -150°C and more preferably between -130°C and -140°C. The first and second cooled and partially liquefied streams 220, 217 are then combined (with the pressure of the second cooled and partially liquefied stream 217 first being regulated, if necessary, and via for example a valve 217A, to control the flow of stream 217) to form a partially liquefied MCSG feed stream 230.

[0081] The partially liquefied MCSG feed stream 230 is then further cooled (and further partially liquefied) in a third heat exchanger unit or set of units 231 to form a partially liquefied MCSG feed stream 233 at a temperature of between -155°C and -185°C and more preferably between -165°C and -175°C. The third heat exchanger unit or set of units 231 may for example comprise a plate fin exchanger unit or a plurality of plate fin exchanger units arranged in parallel. In an alternative embodiment (not depicted), the third heat exchanger unit(s) may be combined with the second heat exchanger unit(s) into a single unit, or set of units in parallel, with stream 215 being cooled in a warmer section of said unit(s) and stream 230 being cooled in a colder section of said unit(s).

[0082] The partially liquefied MCSG feed stream 233 is then separated using a first phase separator 235 and a second phase separator 240 arranged in series, with the second phase separator being in downstream fluid flow communication with the first phase separator. More specifically, the partially liquefied MCSG stream 233 is first introduced into the first phase separator 235, which in this case is a flash drum, in which the partially liquefied MCSG feed stream is flashed and separated into a liquid steam that forms a third feed stream 236, and a vapor stream that forms a first residue gas stream 237. The third feed stream 236 is reduced in pressure and partially vaporized, for example by passing the stream through J-T valve 237A, after which said stream is two-phase, after which the partially vaporized two-phase third feed stream is then introduced into the second phase separator 240, which in this case is a flash drum, in which the partially liquefied third feed stream is flashed and separated into a liquid stream that forms a first feed stream 242 and a vapor stream that forms a second feed stream 251.

[0083] The first feed stream 242, the flow which is controlled by valve 242A in order to control the liquid level in the second phase separator 240, is passed through and warmed in the third heat exchanger unit or set of units 231, via indirect heat exchange with the partially liquefied MCSG feed stream 230, after which said stream will be two-phase (or in the alternative embodiment where the third heat exchanger unit(s) are combined with the second heat exchanger unit(s), the third feed stream 242 is warmed in the colder section of said combined unit(s)). The first feed stream 252 and second feed stream 251 are then each introduced into different locations of a distillation column 245, as will be further described below, which distillation column 245 operates at a pressure of between 3.0 and 7.0 bara, and more preferably between 4.5 and 5.5 bara.

[0084] The first feed stream 252 is introduced into the distillation column 245 at a first location that is above one or more separation stages of the column that are represented in Figure 2 by section 245C of the column, and that is below one or more separation stages of the column that are represented in Figure 1 by section 245B of the column. The second feed stream 251 is introduced into the distillation column at a second location that is above the one or more separation stages of the column that are represented by section 245B, and that is below one or more separation stages of the column that are represented in Figure 2 by section 245A of the column.

[0085] Reboiler duty for the distillation column 245 is provided warming and thereby at least partially vaporizing a stream of distillation column bottoms liquid 253 in the second heat exchanger unit or set of units 116, via indirect heat exchange with the second stream 215 (obtained from dividing the MCSG feed stream), thereby forming a boil-up stream 254 (formed of said partially vaporized distillation column bottoms liquid) that is reintroduced into the bottom of the distillation column.

[0086] An LNG stream 280 formed of distillation column bottoms liquid is withdrawn from the bottom of the distillation column 245 at a temperature between -125°C and -155°C, and more preferably between -135°C and -145°C, and is preferably increased in pressure in pump 181 and sent (as stream 283) to and passed through the first heat exchanger unit or set of units 214 to be subcooled to form a subcooled LNG product stream 287 that can be stored in a LNG storage vessel on-site or transferred directly off-site (for example via a pipeline or a transport vessel). The LNG stream 280, 287 typically contains 1 mole % or less nitrogen, preferably less than 0.5 mole %, and preferably also has a carbon monoxide content of 10 ppm or less. The percent of methane recovered in the LNG stream 280, 287 from the MCSG feed stream 211 can be higher than 95%.

[0087] A second residue gas stream 260 formed of distillation column overhead vapor is withdrawn from the top of the distillation column 245 at a temperature between -160°C and - 190°C, and more preferably between -170°C and -180°C, and typically contains greater than 95 and preferably greater than 98 mole % hydrogen and carbon monoxide.

[0088] The first residue gas stream 237 and second residue gas stream 260 are each passed through and warmed in the third heat exchanger unit or set of units 231 and are then each (c.f. streams 238 and 261) passed through and further warmed in the second heat exchanger unit or set of units 216 resulting in a warmed first residue gas stream 239 and warmed second residue gas stream 262 (or in the alternative embodiment where the third heat exchanger unit(s) are combined with the second heat exchanger unit(s), the first residue gas stream 237 and second residue gas stream 260 are warmed in the colder section of said combined unit(s) and then further warmed in the warmer section of said combined unit(s)). The warmed second residue gas stream 262 is then compressed and cooled in a compressor 263 and aftercooler 265 to form a compressed second residue gas stream 270 that is then divided into two portions 271, 275.

[0089] A first portion 271 of the compressed second residue gas stream, which preferably consists of a minor portion of the compressed second residue gas stream 270, such as between 10% and 30% and more preferably between 15% and 25% of the flow of said stream, is mixed with the warmed first residue gas stream 239 to form a combined residue gas stream 273. The residue gas stream 273 may be used for fuel for the plant or sent to downstream units for further purification, separation, and/or chemical synthesis. Optionally, some or all of stream 239 may be purified to make a hydrogen product and not combined with residue gas stream 271.

[0090] A second portion 275 of the compressed second residue gas stream, which consists of the remainder of the flow of the compressed second residue gas stream 270 and hence preferably consists of a major portion of said stream, is passed through and cooled in the second heat exchanger unit or set of units 216 (or in the alternative embodiment where the third heat exchanger unit(s) are combined with the second heat exchanger unit(s), the second portion 275 is cooled in the warmer section of said combined unit(s)) to form a cooled stream 277 at temperature between -120°C and -150°C and more preferably between -130°C and -140°C. Said cooled stream 277 is then expanded in an expander 279 to form an at least partially liquefied reflux stream 250, having a temperature of between -160°C and -190°C and more preferably between -170°C and -180°C, that is introduced into the distillation column 245 at a third location that is at the top of the column, above the one or more separation stages of the column that are represented by section 245A, thereby providing a source of reflux to the column. The expansion work from expander 279 may for example be recovered by coupling the expander to a compressor which compresses feed or residue gas, or may for example be recovered in a generator.

[0091] The first heat exchanger unit or set of units 214 is a preferably coil-wound unit or set of units, as for example shown in Figure 1A. Any type of refrigeration process as known in the art for the liquefaction of natural gas (including synthetic or substitute natural gases) may be employed in the first heat exchanger unit or set of units 214, such as a single mixed refrigerant process; dual mixed refrigerant process; propane, ammonia or HFC pre-cooled mixed refrigerant process; reverse Brayton cycle using nitrogen, methane or ethane; or multiple fluid cascade cycle. However, in an exemplary embodiment a SMR (single mixed refrigerant) process may be used, such as the one depicted in Figure 1A and described above.

[0092] The method and system of Figure 2 has the same advantages and benefits as the method and system of Figure 1 described above. As compared to the embodiment shown in Figure 1, the embodiment shown in Figure 2 can achieve even higher methane recovery by employing a reflux with very low methane content, thus further improving the methane recovery of the process. However, the embodiment shown in Figure 1 does have a better specific power as compared to the embodiment shown in Figure 2.

[0093] Figure 3 shows a method and system for producing LNG from MCSG in accordance with a third embodiment of the invention. In Figure 3, features that are shared with the first embodiment depicted in Figure 1 have been assigned the same reference numerals increased by a factor of 200. Thus, for example, the partially liquefied MCSG feed stream 330 in Figure 3 corresponds to the partially liquefied MCSG feed stream 130 in Figure 1, and the distillation column 345 in Figure 3 corresponds to the distillation column 145 shown in Figure 1. Unless a feature of Figure 3 is specifically described as being different from the corresponding feature of Figure 1, that feature can be assumed to have the same structure and function as the corresponding feature in Figure 1 described above. Moreover, if that feature does not have a different structure or function, it may not be specifically referred to in the further description of Figure 3 below.

[0094] The embodiment depicted in Figure 3 differs from that depicted in Figure 1 as regards the manner in which the MCSG feed stream is cooled to form the partially liquefied MCSG feed stream, and as regards the manner in which the first heat exchanger unit or set of units is used, the first heat exchanger unit or set of units being used to supply refrigerant and thereby additional refrigeration to the third heat exchanger unit or set of units and second heat exchanger unit or set of units.

[0095] More specifically, in Figure 3 the whole of the MCSG feed stream 311 exiting the pretreatment section 305 is sent to and passed through the second heat exchanger unit or set of units 316, in which the MCSG feed stream 311 is cooled and partially liquefied to form the partially liquefied MCSG feed stream 330, at a temperature of between -130°C and -160°C and more preferably between -140°C and -150°C, that is then separated using the first phase separator 340 and second phase separator 335 arranged in series (as described above in relation to Figure 1). As described above in relation to Figure 1, the second heat exchanger unit or set of units 316 may for example comprise a plate fin exchanger unit or a plurality of plate fin exchanger units arranged in parallel.

[0096] The first heat exchanger unit or set of units 314 is not used to receive and cool any part of the MCSG feed stream. Instead, in the arrangement shown in Figure 3 the first heat exchanger unit or set of units 314 is used to cool a first refrigerant and produce a stream of cooled first refrigerant 390 that is withdrawn from the first heat exchanger unit or set of units 314 and passed through and warmed in the third heat exchanger unit or set of units 331, via indirect heat exchange with the third feed stream 342, thereby providing additional refrigeration (alongside the first residue gas stream 337 and second residue gas stream 360) to said unit(s). The resulting stream of first refrigerant 392 exiting the third heat exchanger unit or set of units 331 is then passed through and further warmed in the second heat exchanger unit or set of units 316, via indirect heat exchange with the MCSG feed stream 311, thereby providing additional refrigeration (alongside the first residue gas stream 338, second residue gas stream 361, and stream of distillation column bottoms liquid 353) to said unit(s). The resulting warmed stream of first refrigerant 395 is then returned to the first heat exchanger unit or set of units 314 to once again be cooled in said unit(s). In those alternative embodiments where the third heat exchanger unit(s) are combined with the second heat exchanger unit(s), the stream of cooled first refrigerant 390 is instead warmed in the colder section of said combined unit(s) and then further warmed in the warmer section of said combined unit(s).

[0097] The first heat exchanger unit or set of units 314 is a preferably coil-wound unit or set of units, as for example shown in Figure 3A. Any type of refrigeration process as known in the art for the liquefaction of natural gas (including synthetic or substitute natural gases) may be employed in the first heat exchanger unit or set of units 314, such as a single mixed refrigerant process; dual mixed refrigerant process; propane, ammonia or HFC pre-cooled mixed refrigerant process; reverse Brayton cycle using nitrogen, methane or ethane; or multiple fluid cascade cycle. However, in an exemplary embodiment a SMR (single mixed refrigerant) process may be used, such as the one depicted in Figure 3A, in which the first refrigerant is a mixed refrigerant.

[0098] As shown in Figure 3A, the coil-wound heat exchanger unit 314 comprises a warm section comprising a warm tube bundle 314A and cold section comprising a cold tube bundle 314B (the terms warm and cold being relative). The LNG steam 383 is passed through and subcooled in the cold tube bundle 114B to form the subcooled LNG product stream 387. Cooling duty is supplied to the warm and cold tube bundles of the coil-wound heat exchanger unit by cooled first refrigerant that passes through and warms and vaporizes in the shell side of the heat exchanger unit. The SMR cycle depicted in Figure 3A that is used to cool the first refrigerant is one that is well known in the art, and so for the sake of brevity will only cursorily be described here. Very briefly, warmed vaporized first refrigerant withdrawn from the shell side at the bottom of the heat exchanger unit is combined with the stream of warmed vaporized first refrigerant 395 (returning from the first heat exchanger unit or set of units 314) and compressed, cooled and separated, in a compression train comprising one or more compressors, aftercoolers and phase separators, into one or more MRL (mixed refrigerant liquid) streams, two being shown in the figure, and one or more MRV (mixed refrigerant vapor) streams, one being shown in the figure. The MRL streams are passed through and cooled in the warm tube bundle, expanded through J-T valves and combined and introduced into the shell side of the heat exchanger unit at the top of the warm bundle to provide vaporizing first refrigerant flowing downwards through the shell side around the tubes of the warm tube bundle.

[0099] The MRV stream is passed through and cooled and at least partially liquefied in the warm and cold tube bundles, to form a stream of cooled first refrigerant that is withdrawn from the top of the cold tube bundle, and that is expanded and divided to form the stream of cooled first refrigerant 390 (that, as described above, is warmed and, in this case, vaporized in the third heat exchanger unit or set of units 331 and second heat exchanger unit or set of units 316) and a stream of cooled first refrigerant that is introduced into the shell side of the first heat exchanger unit 314 at the top of the cold bundle to provide vaporizing first refrigerant flowing downwards through the shell side around the tubes of the cold and warm tube bundles. The stream of cooled first refrigerant that is withdrawn from the top of the cold tube bundle may be expanded, for example by passing the stream through a J-T valve, and then divided to form the stream of cooled first refrigerant 390 and stream of cooled first refrigerant that is introduced into the shell side of the first heat exchanger unit 314 at the top of the cold bundle, as shown in Figure 3A. Alternatively, the stream of cooled first refrigerant that is withdrawn from the top of the cold tube bundle may first be divided, and then the resulting divided streams expanded separately (for example using separate J-T valves).

[0100] The method and system of Figure 3 has similar advantages and benefits to the method and system of Figure 1 described above. As compared to the embodiment shown in Figure 1, the embodiment shown in Figure 3 avoids these need to divide and distribute the MCSG feed stream between the first and second heat exchanger units, but has the potential disadvantage of requiring use of a two-phase refrigerant in the second and/or third heat exchanger unit (i.e. where the first refrigerant used in the second and/or third heat exchanger unit is two-phase).

[0101] Figure 4 shows a method and system for producing LNG from MCSG in accordance with a fourth embodiment of the invention. In Figure 4, features that are shared with the second embodiment depicted in Figure 2 have been assigned the same reference numerals increased by a factor of 200. Thus, for example, the partially liquefied MCSG feed stream 430 in Figure 4 corresponds to the partially liquefied MCSG feed stream 230 in Figure 2, and the distillation column 445 in Figure 4 corresponds to the distillation column 445 in Figure 1. Unless a feature of Figure 4 is specifically described as being different from the corresponding feature of Figure 2, that feature can be assumed to have the same structure and function as the corresponding feature in Figure 2 described above. Moreover, if that feature does not have a different structure or function, it may not be specifically referred to in the further description of Figure 4 below.

[0102] The embodiment depicted in Figure 4 differs from that depicted in Figure 2 as regards the manner in which the MCSG feed stream is cooled to form the partially liquefied MCSG feed stream, and as regards the manner in which the first heat exchanger unit or set of units is used, the first heat exchanger unit or set of units being used to supply refrigerant and thereby additional refrigeration to the third heat exchanger unit or set of units and second heat exchanger unit or set of units.

[0103] More specifically, in Figure 4 the whole of the MCSG feed stream 411 exiting the pretreatment section 405 is sent to and passed through the second heat exchanger unit or set of units 416, in which the MCSG feed stream 411 is cooled and partially liquefied to form the partially liquefied MCSG feed stream 430, at a temperature of between -120°C and -150°C and more preferably between -130°C and -140°C, that is then separated using the first phase separator 435 and second phase separator 440 arranged in series (as described above in relation to Figure 2). As described above in relation to Figure 2, the second heat exchanger unit or set of units 416 may for example comprise a plate fin exchanger unit or a plurality of plate fin exchanger units arranged in parallel.

[0104] The first heat exchanger unit or set of units 414 is not used to receive and cool any part of the MCSG feed stream. Instead, in the arrangement shown in Figure 4 the first heat exchanger unit or set of units 414 is used to cool a first refrigerant and produce a stream of cooled first refrigerant 490 that is withdrawn from the first heat exchanger unit or set of units 414 and passed through and warmed in the third heat exchanger unit or set of units 431, via indirect heat exchange with the partially liquefied MCSG feed stream 430, thereby providing additional refrigeration (alongside the first residue gas stream 437, second residue gas stream 460 and first feed stream 442) to said unit(s). The resulting stream of first refrigerant 492 exiting the third heat exchanger unit or set of units 431 is then passed through and further warmed in the second heat exchanger unit or set of units 416, via indirect heat exchange with the MCSG feed stream 411, thereby providing additional refrigeration (alongside the first residue gas stream 438, second residue gas stream 461, and stream of distillation column bottoms liquid 453) to said unit(s). The resulting warmed stream of first refrigerant 495 is then returned to the first heat exchanger unit or set of units 414 to once again be cooled in said unit(s). In those alternative embodiments where the third heat exchanger unit(s) are combined with the second heat exchanger unit(s), the stream of cooled first refrigerant 490 is instead warmed in the colder section of said combined unit(s) and then further warmed in the warmer section of said combined unit(s).

[0105] The first heat exchanger unit or set of units 414 is a preferably coil-wound unit or set of units, as for example shown in Figure 3A. Any type of refrigeration process as known in the art for the liquefaction of natural gas (including synthetic or substitute natural gases) may be employed in the first heat exchanger unit or set of units 414, such as a single mixed refrigerant process; dual mixed refrigerant process; propane, ammonia or HFC pre-cooled mixed refrigerant process; reverse Brayton cycle using nitrogen, methane or ethane; or multiple fluid cascade cycle. However, in an exemplary embodiment a SMR (single mixed refrigerant) process may be used, such as the one depicted in Figure 3A and described above.

[0106] The method and system of Figure 4 has the same advantages and benefits as the method and system of Figure 3 described above. As compared to the embodiment shown in Figure 3, the embodiment shown in Figure 4 can achieve even higher methane recovery by employing a reflux with very low methane content, thus further improving the methane recovery of the process. However, the embodiment shown in Figure 3 does have a better specific power as compared to the embodiment shown in Figure 4.

EXAMPLE 1

[0107] In this example, a method and system for producing liquefied natural gas (LNG) from a methane-containing synthetic gas (MCSG) as depicted in Figure 1 was simulated, using Aspen version 10. Table 1 below provides stream data from the simulation. In this example, the residue gas compressor 163 has four stages with an approximate break horsepower of 61.8 MW, the mixed refrigerant compressor 115 A and 115B has an approximate break horsepower of 30.3 MW, the expander 179 extracts 10.5 MW of work and the process has a methane recovery of 95%.

Table 1: Heat and Material Balance

Stream #		111	113	115	117	120	141	142	143	133	137	138	139	150
Temperature	°C	30.0	30.0	30.0	-143.2	-144.9	-143.9	-143.9	-143.9	-183.6	-183.6	-146.9	26.1	-183.6
Pressure	bara	37.0	37.0	37.0	36.8	35.6	35.6	35.6	35.6	35.4	35.4	35.1	34.9	35.4
Vapor Fraction	-	1.00	1.00	1.00	0.89	0.87	1.00	1.00	1.00	0.67	1.00	1.00	1.00	0.00
Flow	kgmol/hr	36,862	9,061	27,802	27,802	9,061	32,645	10,524	22,120	10,524	7,036	7,036	7,036	3,488
Composition	mol%													
H2		56.47	56.47	56.47	56.47	56.47	63.27	63.27	63.27	63.27	92.04	92.04	92.04	5.24
CO		24.21	24.21	24.21	24.21	24.21	24.23	24.23	24.23	24.23	7.53	7.53	7.53	57.92
CD		0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2		0.13	0.13	0.13	0.13	0.13	0.14	0.14	0.14	0.14	0.06	0.06	0.06	0.29
AR		0.08	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.02	0.02	0.02	0.19
C1		18.89	18.89	18.89	18.89	18.89	12.27	12.27	12.27	12.27	0.35	0.35	0.35	36.31
EL		0.21	0.21	0.21	0.21	0.21	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.04
Total		100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Stream #		151	152	153	154	160	161	162	164	170	173	180	183	187
Temperature	°C	-183.6	-143.9	-145.6	-145.5	-186.6	-146.9	26.1	109.8	30.0	29.0	-145.5	-144.9	-159.4
Pressure	bara	3.0	35.6	3.1	3.1	3.0	2.7	2.5	35.4	34.9	34.9	3.1	15.2	11.7
Vapor Fraction	-	0.87	0.00	0.00	0.28	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00
Flow	kgmol/hr	22,120	4,218	9,351	9,351	23,129	23,129	23,129	23,129	23,129	30,166	6,697	6,697	6,697
Composition	mol%													
H2		63.27	3.86	0.00	0.00	62.00	62.00	62.00	62.00	62.00	69.01	0.00	0.00	0.00
CO		24.23	24.03	0.00	0.00	36.29	36.29	36.29	36.29	36.29	29.58	0.00	0.00	0.00
CD		0.00	0.08	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.06	0.06

(continued)

Stream #		111	113	115	117	120	141	142	143	133	137	138	139	150
N2		0.14	0.10	0.00	0.00	0.19	0.19	0.19	0.19	0.19	0.16	0.00	0.00	0.00
AR		0.07	0.10	0.03	0.03	0.11	0.11	0.11	0.11	0.11	0.09	0.01	0.01	0.01
C1		12.27	70.14	99.10	99.10	1.40	1.40	1.40	1.40	1.40	1.15	98.79	98.79	98.79
EL		0.01	1.70	0.83	0.83	0.00	0.00	0.00	0.00	0.00	0.00	1.14	1.14	1.14
Total		100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

EXAMPLE 2

[0108] In this example, a method and system for producing liquefied natural gas (LNG) from a methane containing synthetic gas (MCSG) as depicted in Figure 2 was simulated, using Aspen version 10. Table 2 below provides stream data from the simulation.

Table 2: Heat and Material Balance

Stream #		211	213	215	217	220	230	233	236	237	238	239	242	250	251	252
Temperature	°C	30.0	30.0	30.0	-135.7	-137.2	-136.4	-171.8	-171.8	-171.8	-139.4	25.6	-174.7	-176.7	-174.7	-155.4
Pressure	bara	37.0	37.0	37.0	36.8	35.6	356	35.4	35.4	35.4	35.1	34.9	5.2	4.7	5.2	4.8
Vapor Fraction		100	1.00	1.00	0.98	0.97	0.98	0.64	0.00	1.00	1.00	1.00	0.00	0.80	1.00	0.51
Flow	- kgmol/hr	36,862	11,091	25,771	25,771	11,091	36.862	36,862	13,222	23,641	23,641	23,641	11.982	25,692	1,240	11.982
Composition	mol%															
H2		56.47	56.47	56.47	56.47	56.47	5647	56.47	4.77	85.39	85.39	85.39	0.37	9.66	47.26	0.37
CO		24.21	24.21	2421	2421	24.21	2421	24.21	44.14	1306	13.06	13.06	43.72	8944	48.22	43.72
CD		0.01	0.01	001	0.01	0.01	0.01	0.01	0.03	0.00	0.00	0.00	0.03	0.00	000	0.03
N2		0.13	0.13	0.13	0.13	013	0.13	0.13	0.20	0.09	0.09	0.09	0.19	0.41	0.35	0.19
AR		0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.16	0.03	0.03	003	0.16	0.31	0.11	0.16
C1		18.89	18.89	18.89	18.89	18.89	18.89	18.89	50.13	1.42	142	142	54.89	0.18	4.07	54.89
EL		0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.58	0.00	0.00	0.00	0.64	0.00	0.00	0.64
Total		100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Stream #		253	254	260	261	262	264	270	271	273	275	277	280	283	287	
Temperature	°C	-137.9	-137.8	-176.3	-139.4	25.6	95.4	30.0	30.0	25.9	300	-135.7	-137.8	-137.2	-159.4	
Pressure	bara	4.9	4.9	4.7	4.5	4.2	39.4	38.9	38.9	34.9	38.9	384	49	15.2	11.7	
Vapor Fraction	-	0.00	0.29	1.00	1.00	1.00	100	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	
Flow	kgmol/hr	9.414	9.414	32.217	32,217	32,217	32,217	32.217	6,526	30,166	25,692	25.692	6,697	6,697	6,697	
Composition	mol%															
H2		0.00	0.00	9.66	9.66	9.66	9.66	9.66	9.66	69.01	9.66	9.66	0.00	0.00	0.00	
CO		0.00	0.00	89.44	89.44	89.44	89.44	89.44	89.44	29.58	89.44	89.44	0.00	0.00	0.00	

(continued)

Stream #		211	213	215	217	220	230	233	236	237	238	239	242	250	251	252
CD		004	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	000	0.05	0.05	0.05	
N2		0.00	0.00	0.41	0.41	0.41	041	0.41	0.41	0.16	041	0.41	0.00	0.00	0.00	
AR		0.01	001	0.31	0.31	0.31	0.31	031	0.31	0.09	0.31	0.31	0.00	0.00	0.00	
C1		99.12	99.12	0.18	018	0.18	0.18	018	0.18	1.15	0.18	0.18	98.80	98.80	98.80	
EL		0.82	0.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.14	1.14	1.14	
Total		100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	

[0109] The method and system in this Example uses a heat pump (expander 279) to allow extremely high product recovery. It produces a high purity reflux with very low methane content, thus improving the methane recovery of the process as compared to the process of Example 1. However, the process of Example 1 has a better specific power compared to the process of Example 2, 848.5 vs 922.6 kW-hr/tonne.

[0110] It will be appreciated that the invention is not restricted to the details described above with reference to the preferred embodiments but that numerous modifications and variations can be made without departing from the spirit or scope of the invention as defined in the following claims.

Claims

1. A method for producing liquefied natural gas (LNG) from methane-containing synthetic gas (MCSG), the method comprising:

    (a) cooling and partially liquefying a MCSG feed stream to produce a partially liquefied MCSG feed stream;
    (b) using a first phase separator and a second phase separator arranged in series, with the second phase separator being in downstream fluid flow communication with the first phase separator, to separate the partially liquefied MCSG feed stream into at least three streams comprising a liquid stream and two vapor streams, the liquid stream forming a first feed stream, one of the vapor streams forming a second feed stream, and the other of the vapor streams forming a first residue gas stream;
    (c) introducing the first feed stream into a distillation column at a first location;
    (d) introducing the second feed stream into the distillation column at a second location that is above the first location, there being at least one separation stage between the first location and second location;
    (e) withdrawing an LNG stream from the distillation column formed of distillation column bottoms liquid; and
    (f) withdrawing a second residue gas stream from the distillation column formed of distillation column overhead vapor.

2. The method of Claim 1, wherein step (b) comprises:

    (i) separating the partially liquefied MCSG feed stream in the first phase separator into the liquid steam that forms the first feed stream, and a vapor stream;
    (ii) dividing the vapor stream from the first phase separator to form the vapor stream that forms the second feed stream, and a vapor stream that forms a third feed stream; and
    (iii) cooling and partially liquefying the third feed stream and then separating the third feed stream in the second phase separator into the vapor stream that forms the first residue gas stream, and a liquid stream that forms a fourth feed stream;
    wherein step (c) comprises reducing the pressure of the first feed stream and then introducing the first feed stream into a distillation column at the first location;
    wherein step (d) comprises reducing the pressure of the second feed stream and then introducing the second feed stream into the distillation column at the second location; and
    wherein the method further comprises reducing the pressure of the fourth feed stream and then introducing the fourth feed stream into the distillation column at a third location that is above the second location, there being at least one separation stage between the second location and third location.

3. The method of Claim 2, wherein the third location is at the top of the distillation column.

4. The method of Claim 2 or 3, wherein one or both of the first residue gas stream and the second residue gas stream are warmed via indirect heat exchange with the third feed stream in order to provide cooling duty for the cooling and partial liquefaction of the third feed stream in step (b)(iii).

5. The method of Claim 1, wherein step (b) comprises:

    (i) separating the partially liquefied MCSG stream in the first phase separator into the vapor stream that forms the first residue gas stream, and a liquid stream that forms a third feed stream; and
    (ii) reducing the pressure of and partially vaporizing the third feed stream and separating said stream in the second phase separator into the liquid stream that forms the first feed stream and the vapor stream that forms the second feed stream; and

wherein step (c) comprises warming the first feed stream and then introducing the first feed stream into a distillation column at the first location.

6. The method of Claim 5, wherein there is at least one separation stage between the second location and the top of the column, and the method further comprises: compressing, cooling, expanding and thereby at least partially liquefying a portion of the second residue gas stream or distillation column overhead vapor to form a reflux stream; and introducing the reflux stream into the distillation column at a third location that is at the top of the distillation column.

7. The method of Claim 5 or 6, wherein in step (c) the first feed stream is warmed via indirect heat exchange with the MCSG feed stream in order to provide cooling duty for the cooling and partial liquefaction of the MCSG feed stream in step (a).

8. The method of any one of Claims 1 to 7, wherein one or both of the first residue gas stream and the second residue gas stream are warmed via indirect heat exchange with the MCSG feed stream in order to provide cooling duty for the cooling and partial liquefaction of the MCSG feed stream in step (a).

9. The method of any one of Claims 1 to 8, wherein there is at least one separation stage between the first location and the bottom of the column, and wherein the method further comprises warming and thereby at least partially vaporizing a portion of the LNG stream or distillation column bottoms liquid to form a boil-up stream, and introducing the boil-up stream into the distillation column at the bottom of the distillation column.

10. The method of any one of Claims 1 to 9, wherein step (a) comprises:

(i) dividing the MCSG feed stream into at least two portions, comprising a first portion and a second portion;
(ii) cooling and partially liquefying the first portion of the MCSG feed stream in a first heat exchanger unit or set of units via indirect heat exchange with a first refrigerant, wherein the first heat exchanger unit or set of units is a coil-wound heat exchanger unit or set of units;
(iii) cooling and partially liquefying the second portion of the MCSG feed stream in a second heat exchanger unit or set of units via indirect heat exchange with one or more process streams; and
(iv) combining the cooled and partially liquefied first portion of the MCSG feed stream and the cooled and partially liquefied second portion of the MCSG feed stream to form the partially liquefied MCSG feed stream.

11. The method of any one of Claims 1 to 9, wherein step (a) comprises:

(i) cooling a first refrigerant in a first heat exchanger unit or set of units to produce a cooled first refrigerant, wherein the first heat exchanger unit or set of units is a coil-wound heat exchanger unit or set of units;
(ii) cooling and partially liquefying the MCSG feed stream in a second heat exchanger unit or set of units, via indirect heat exchange with one or more streams of the cooled first refrigerant and one or more process streams, to form the partially liquefied MCSG feed stream.

12. A method for producing liquefied natural gas (LNG) from methane containing synthetic gas (MCSG), the method comprising:

(a) cooling and partially liquefying a MCSG feed stream to produce a partially liquefied MCSG feed stream by:

(i) dividing the MCSG feed stream into at least two portions, comprising a first portion and a second portion;
(ii) cooling and partially liquefying the first portion in a first heat exchanger unit or set of units via indirect heat exchange with a first refrigerant, wherein the first heat exchanger unit or set of units is a coil-wound heat exchanger unit or set of units;
(iii) cooling and partially liquefying the second portion in a second heat exchanger unit or set of units via indirect heat exchange with one or more process streams; and
(iv) combining the cooled and partially liquefied first portion and the cooled and partially liquefied second portion to form the partially liquefied MCSG feed stream;

(b) separating the partially liquefied MCSG feed stream into a LNG stream and one or more residue gas streams.

13. The method of Claim 10 or 12, wherein the second heat exchanger unit or set of units is a plate fin heat exchanger unit or set of units;

wherein in step (a)(iii) the one or more process streams comprise one or more streams selected from the one or more of the residue gas streams, a portion of the LNG stream or a portion of a distillation column bottoms liquid; and

wherein step (a)(ii) comprises cooling and partially liquefying the first portion of the MCSG feed stream in the first heat exchanger unit or set of units via indirect heat exchange with one or more streams of cooled first refrigerant, wherein the first heat exchanger unit or set of units is a coil-wound heat exchanger unit or set of units, and wherein the one or more streams of cooled first refrigerant are produced by also cooling the first refrigerant in the first heat exchanger unit or set of units.

14. A method for producing liquefied natural gas (LNG) from methane containing synthetic gas (MCSG), the method comprising:

(a) cooling and partially liquefying a MCSG feed stream to produce a partially liquefied MCSG feed stream by:

(i) cooling a first refrigerant in a first heat exchanger unit or set of units to produce a cooled first refrigerant, wherein the first heat exchanger unit or set of units is a coil-wound heat exchanger unit or set of units;
(ii) cooling and partially liquefying the MCSG feed stream in a second heat exchanger unit or set of units, via indirect heat exchange with one or more streams of the cooled first refrigerant and one or more process streams, to form the partially liquefied MCSG feed stream;

(b) separating the partially liquefied MCSG feed stream into a LNG stream and one or more residue gas streams.

15. The method of Claim 11 or 14, wherein the second heat exchanger unit or set of units is a plate fin heat exchanger unit or set of units;

wherein in step (a)(ii) the one or more process streams comprise one or more streams selected from one or more of the residue gas streams, a portion of the LNG stream or a portion of a distillation column bottoms liquid; and

wherein in step (a)(i) the first refrigerant is cooled in the first heat exchanger unit or set of units via indirect heat exchange with a portion of the cooled first refrigerant that is produced in step (a)(i).

16. A system for producing liquefied natural gas (LNG) from methane containing synthetic gas (MCSG), the system comprising:

one or more heat exchanger units for receiving, cooling and partially liquefying a MCSG feed stream to produce a partially liquefied MCSG feed stream;

a first phase separator and a second phase separator in fluid flow communication with the one or more heat exchanger units and arranged in series, with the second phase separator being in downstream fluid flow communication with the first phase separator, for separating the partially liquefied MCSG feed stream into at least three streams comprising a liquid stream and two vapor streams, the liquid stream forming a first feed stream, one of the vapor streams forming a second feed stream, and the other of the vapor streams forming a first residue gas stream; and

a distillation column having: a first inlet at a first location for receiving the first feed stream; a second inlet at second location for receiving the second feed stream, the second location being above the first location; at least one separation stage between the first location and second location; an outlet at the bottom of the distillation column for withdrawal of an LNG stream formed of distillation column bottoms liquid; and an outlet at the top of the distillation column for withdrawal of a second residue gas stream formed of distillation column overhead vapor.

17. A system for producing liquefied natural gas (LNG) from methane containing synthetic gas (MCSG), the system comprising:

a set of conduits for dividing a MCSG feed stream into at least two portions, comprising a first portion and a second portion;

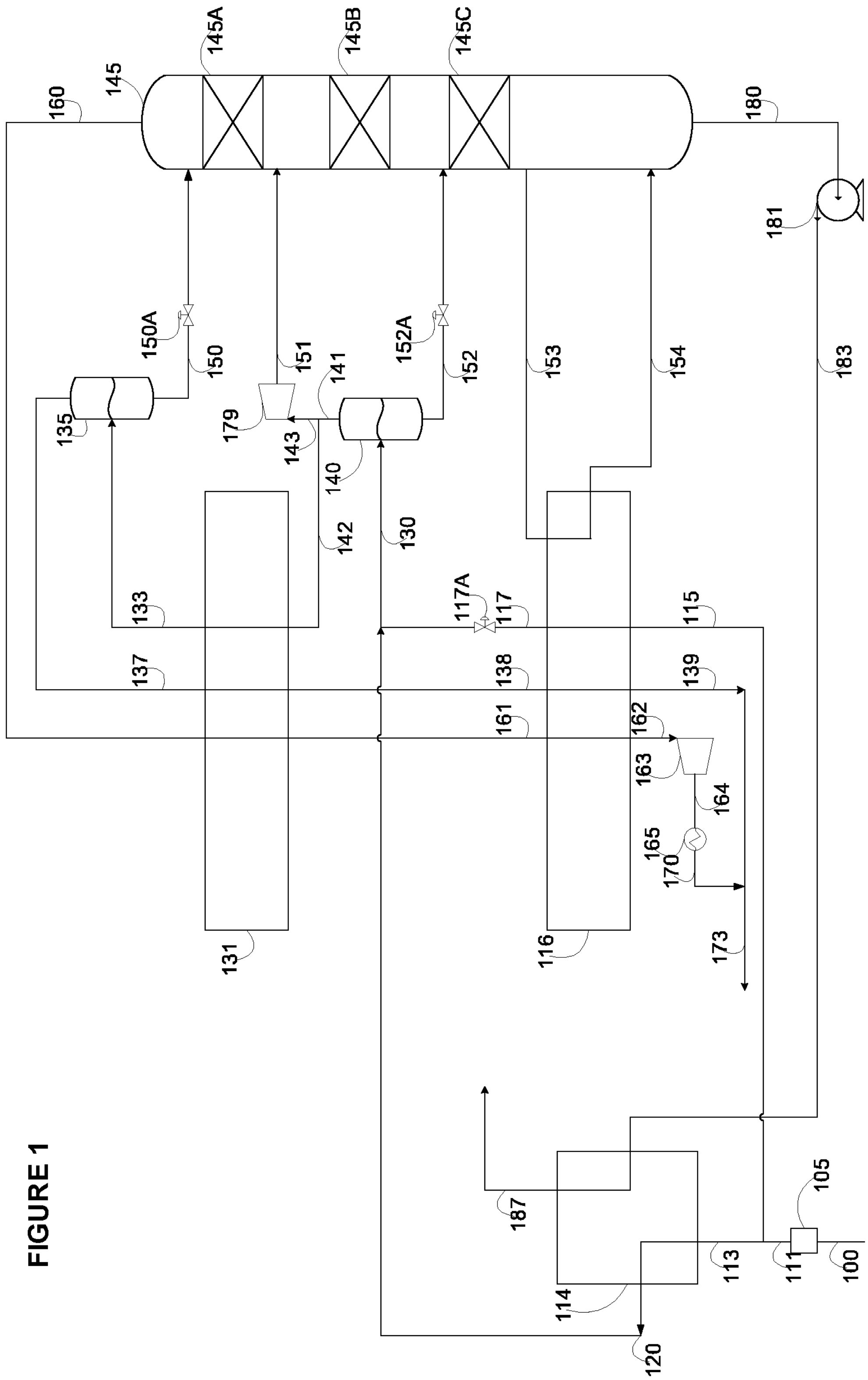
a first heat exchanger unit or set of units via for receiving the first portion and cooling and partially liquefying the first portion via indirect heat exchange with a first refrigerant, wherein the first heat exchanger unit or set of units is a coil-wound heat exchanger unit or set of units;

a second heat exchanger unit or set of units for receiving the second portion and cooling and partially liquefying

the second portion via indirect heat exchange with one or more process streams;
a set of conduits for receiving and combining the cooled and partially liquefied first portion and the cooled and partially liquefied second portion to form a partially liquefied MCSG feed stream; and
one or more phase separators and/or one or more distillation columns for receiving and separating the partially liquefied MCSG feed stream into a LNG stream and one or more residue gas streams.

18. A system for producing liquefied natural gas (LNG) from methane containing synthetic gas (MCSG), the system comprising:

a first heat exchanger unit or set of units for cooling a first refrigerant to produce a cooled first refrigerant, wherein the first heat exchanger unit or set of units is a coil-wound heat exchanger unit or set of units;
a second heat exchanger unit or set of units for receiving one or more streams of the cooled first refrigerant from the first heat exchanger unit, for receiving one or more process streams, and for receiving an MCSG feed stream and cooling and partially liquefying the MCSG feed stream to form a partially liquefied MCSG feed stream via indirect heat exchange with the one or more streams of the cooled first refrigerant and the one or more process streams; and
one or more phase separators and/or one or more distillation columns for receiving and separating the partially liquefied MCSG feed stream into a LNG stream and one or more residue gas streams.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142
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117A
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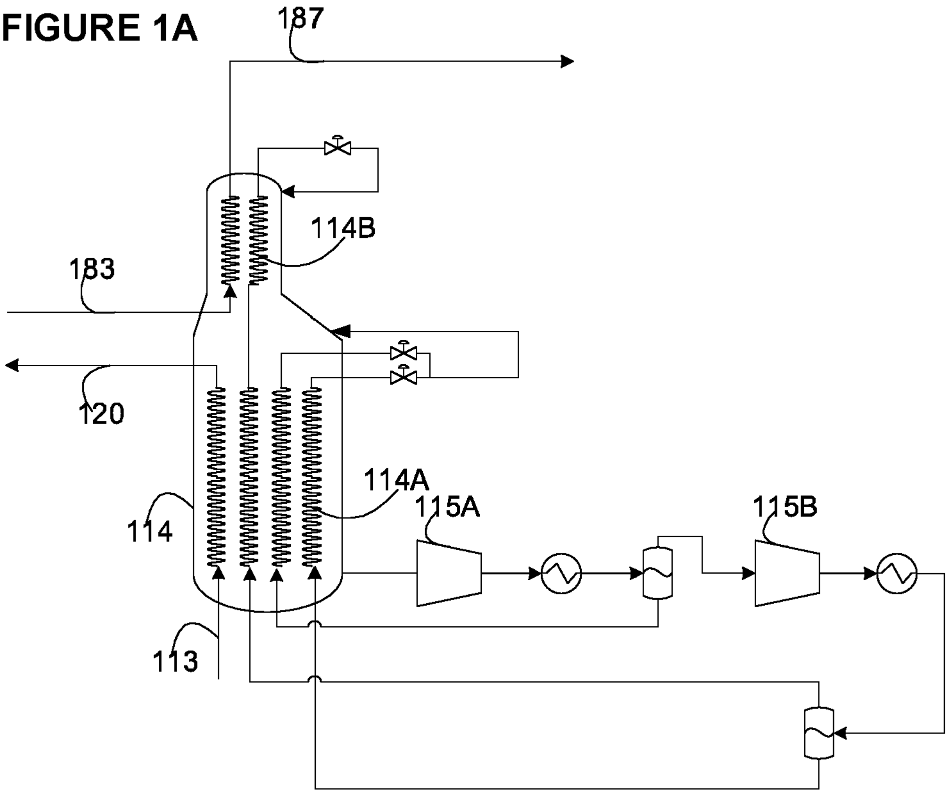
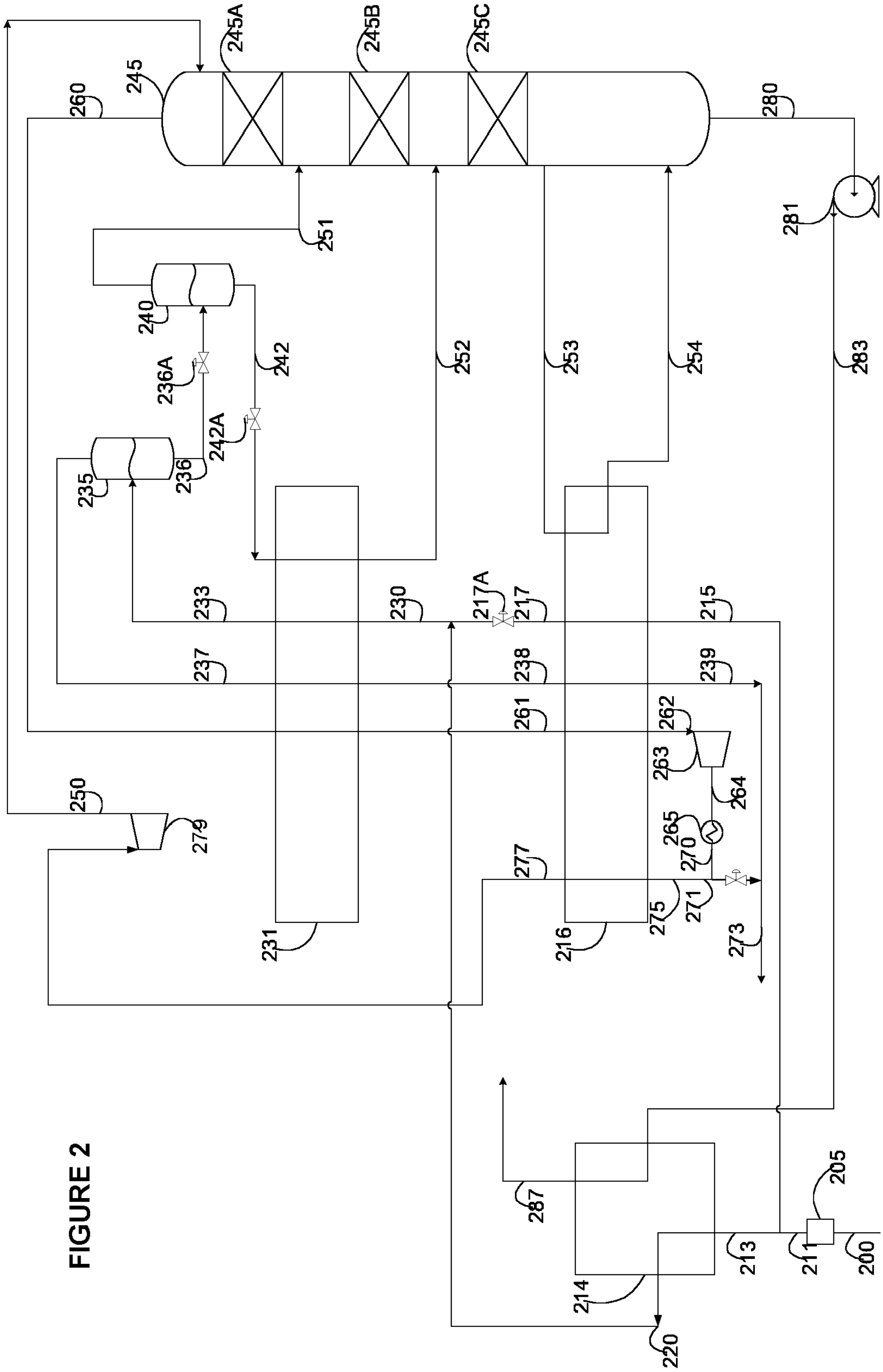
FIGURE 1

FIGURE 1A

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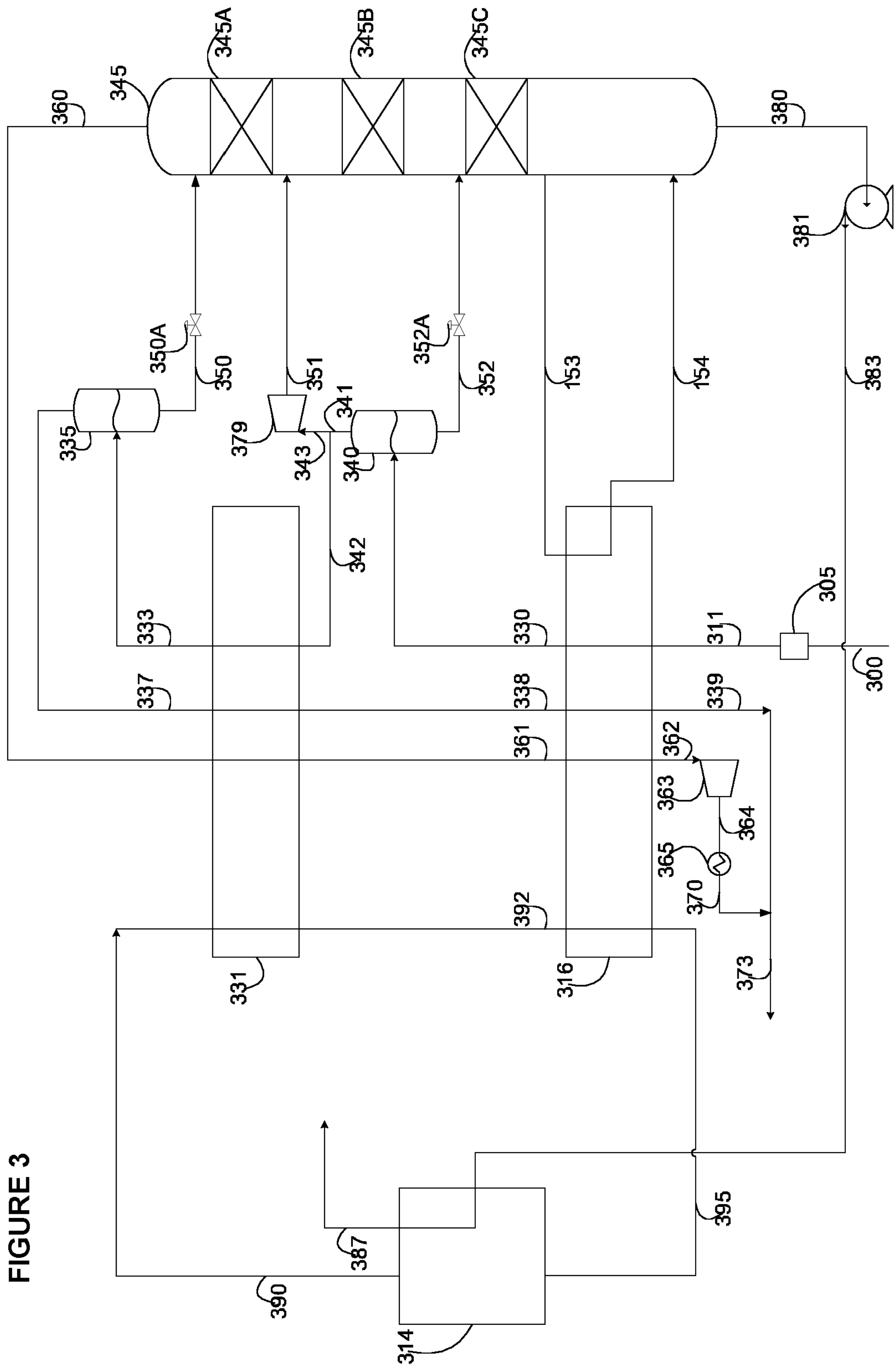
220

FIGURE 2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345B
345C
345
360
380
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350A
350
351
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352A
352
153
154
335
379
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340
342
305
333
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361
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365
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392
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387
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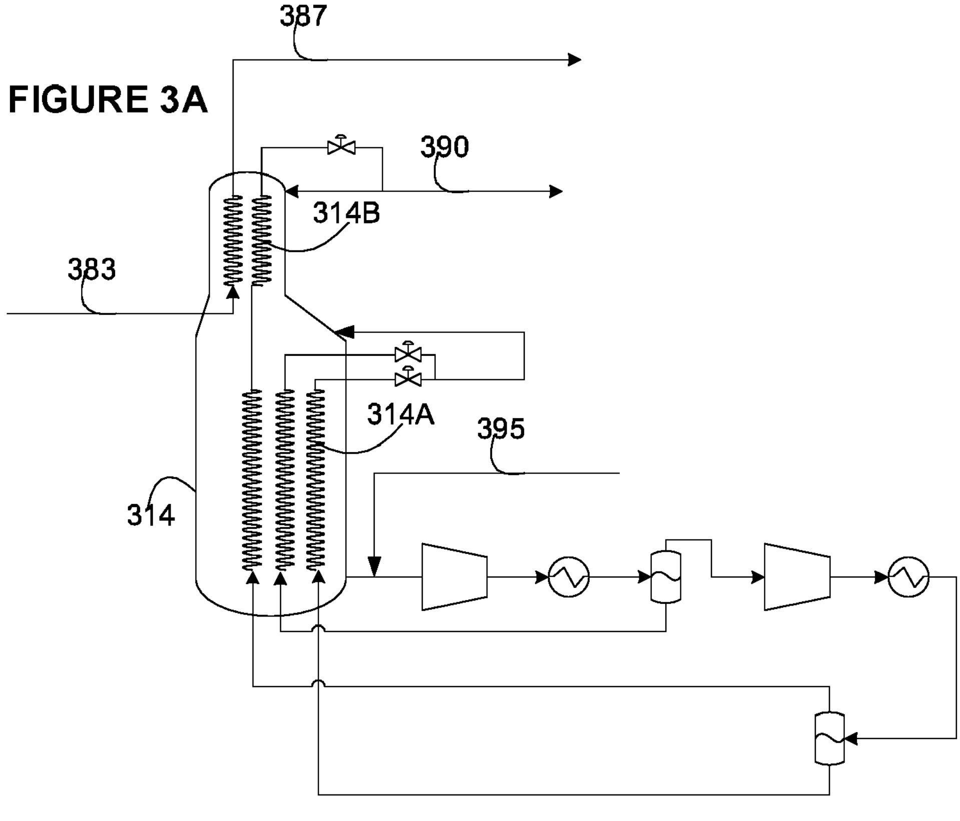
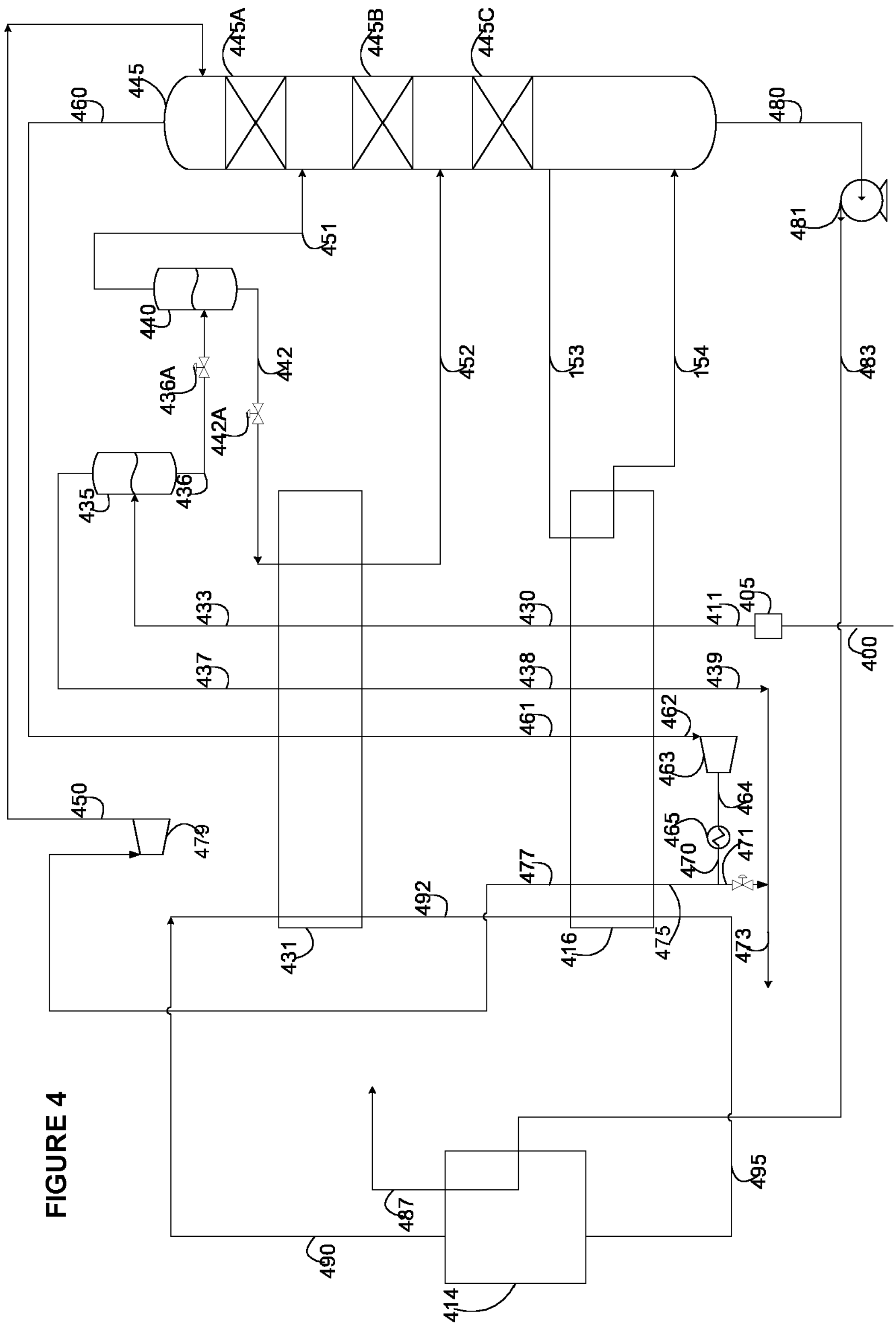
FIGURE 3

FIGURE 3A

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445B
445C
445
460
480
481
451
440
452
153
154
483
442
436A
442A
435
436
433
430
411
405
400
437
438
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464
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490
414

FIGURE 4

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 10436505 B **[0003] [0006]**