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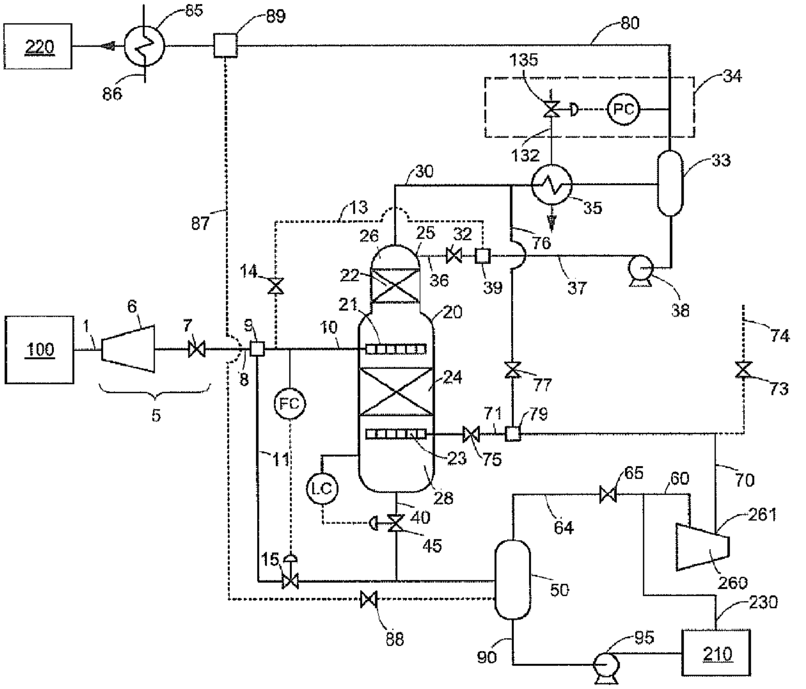
(54) Titre : PROCEDE ET APPAREIL POUR RETIRER L'AZOTE D'UNE COMPOSITION D'HYDROCARBURES CRYOGENIQUES

(54) Title: METHOD AND APPARATUS FOR REMOVING NITROGEN FROM A CRYOGENIC HYDROCARBON COMPOSITION



(57) Abrégé/Abstract:
Nitrogen is removed from a cryogenic hydrocarbon composition. A least a first portion of the cryogenic hydrocarbon composition is fed to a nitrogen stripper column as a first nitrogen stripper feed stream. A nitrogen-stripped liquid is drawn from the nitrogen

(57) **Abrégé(suite)/Abstract(continued):**

stripper column. A liquid hydrocarbon product stream and a process vapour are produced comprising at least a step of depressurizing the nitrogen-stripped liquid to a flash pressure. The process vapour is compressed, and selectively split into a stripping portion and a non-stripping portion. A stripping vapour stream comprising at least the stripping portion is passed into the nitrogen stripper column. A vapour fraction is discharged as off gas, comprising a discharge fraction of overhead vapour from the nitrogen stripper column and comprising at least the bypass portion from the non-stripping portion of the compressed vapour, which bypasses a stripping section positioned in the nitrogen stripper column.

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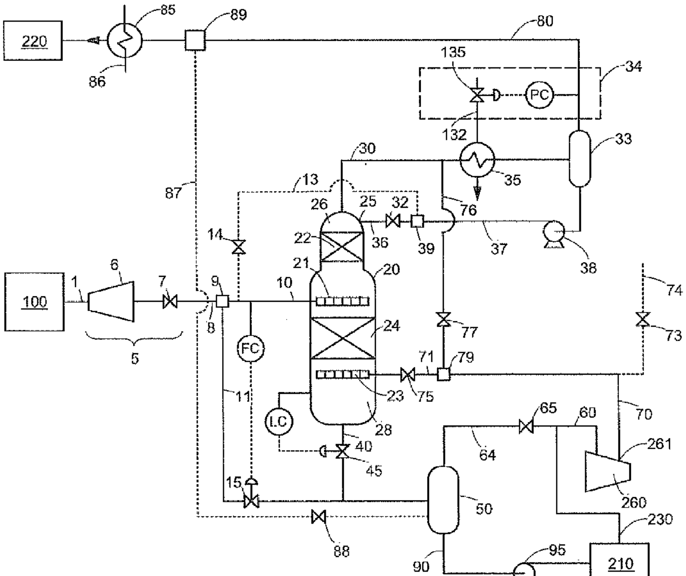

FIG. 1

(57) Abstract: Nitrogen is removed from a cryogenic hydrocarbon composition. A least a first portion of the cryogenic hydrocarbon composition is fed to a nitrogen stripper column as a first nitrogen stripper feed stream. A nitrogen-stripped liquid is drawn from the nitrogen stripper column. A liquid hydrocarbon product stream and a process vapour are produced comprising at least a step of depressurizing the nitrogen-stripped liquid to a flash pressure. The process vapour is compressed, and selectively split into a stripping portion and a non-stripping portion. A stripping vapour stream comprising at least the stripping portion is passed into the nitrogen stripper column. A vapour fraction is discharged as off gas, comprising a discharge fraction of overhead vapour from the nitrogen stripper column and comprising at least the bypass portion from the non-stripping portion of the compressed vapour, which bypasses a stripping section positioned in the nitrogen stripper column.

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METHOD AND APPARATUS FOR REMOVING NITROGEN FROM A CRYOGENIC HYDROCARBON COMPOSITION

The present invention relates to a method and apparatus for removing nitrogen from a cryogenic hydrocarbon composition.

Liquefied natural gas (LNG) forms an economically important example of such a cryogenic hydrocarbon composition. Natural gas is a useful fuel source, as well as a source of various hydrocarbon compounds. It is often desirable to liquefy natural gas in a liquefied natural gas plant at or near the source of a natural gas stream for a number of reasons. As an example, natural gas can be stored and transported over long distances more readily as a liquid than in gaseous form because it occupies a smaller volume and does not need to be stored at high pressure.

WO 2011/009832 describes a method for treating a multi-phase hydrocarbon stream produced from natural gas, wherein lower boiling point components, such as nitrogen, are separated from the multi-phase hydrocarbon stream, to produce a liquefied natural gas stream with a lower content of such lower boiling point components. It employs two subsequent gas/liquid separators operating at different pressures. The multi-phase hydrocarbon stream is fed into the first gas/liquid separator at a first pressure. The bottom stream of the first gas/liquid separator is passed to the second gas/liquid separator, which provides vapour at a second pressure that is lower than the first pressure. The vapour is compressed in an overhead stream compressor, and returned to the first gas/liquid separator as a stripping vapour stream. Compressed boil-off gas from a cryogenic storage tank may be added to the stripping vapour stream. The first gas/liquid separator comprises a contacting zone, with contact enhancing means such as trays or packing, arranged gravitationally between the inlet for the multiphase hydrocarbon stream into the first gas/liquid separator and the inlet for the stripping vapour stream. A low pressure fuel gas stream is prepared from the overhead vapour stream discharged from the first gas/liquid separator, which low pressure fuel gas stream is passed to a combustion device.

A drawback of the method and apparatus as described in WO 2011/009832 is that the equilibrium in the first gas/liquid separator can be disturbed if the amount of stripping vapour changes substantially, which could be the case when the plant transits between holding mode and loading mode operation.

The present invention provides a method of removing nitrogen from a cryogenic hydrocarbon composition comprising a nitrogen- and methane-containing liquid phase, the method comprising:

- providing a cryogenic hydrocarbon composition comprising a nitrogen- and methane-containing liquid phase;
- feeding a first nitrogen stripper feed stream, at a stripping pressure, into a nitrogen stripper column comprising at least one internal stripping section positioned within the nitrogen stripper column, said first nitrogen stripper feed stream comprising a first portion of the cryogenic hydrocarbon composition;

- drawing a nitrogen-stripped liquid from a sump space of the nitrogen stripper column below the stripping section;
- producing at least a liquid hydrocarbon product stream and a process vapour from the nitrogen-stripped liquid, comprising at least a step of depressurizing the nitrogen-stripped liquid to a flash pressure;
- compressing said process vapour to at least the stripping pressure, thereby obtaining a compressed vapour;
- selectively splitting the compressed vapour into a stripping portion and a non-stripping portion that does not comprise the stripping portion, which non-stripping portion comprises a bypass portion of said compressed vapour;
- passing a stripping vapour stream into the nitrogen stripper column at a level gravitationally below said stripping section, said stripping vapour stream comprising at least the stripping portion of said compressed vapour;
- passing an intermediate vapour through a condenser whereby indirectly heat exchanging of the intermediate vapour against an auxiliary refrigerant stream and partially condensing the intermediate vapour, wherein said intermediate vapour comprises at least the non-stripping portion of said compressed vapour, and wherein said heat exchanging comprises passing heat from the intermediate vapour to the auxiliary refrigerant stream at a cooling duty, whereby an excess liquid is formed from the intermediate vapour and whereby at least said bypass portion from the compressed vapour remains in vapour phase;

- discharging a vapour fraction as off gas, comprising a discharge fraction of an overhead vapour obtained from an overhead space of the nitrogen stripper column and comprising at least the bypass portion; and
- returning at least part of a liquid recycle portion to the liquid hydrocarbon product stream, wherein the liquid recycle portion comprises at least part of the excess liquid;

wherein from said selectively splitting to the discharging of the bypass portion in the vapour fraction of the off gas the bypass portion bypasses the at least one internal stripping section.

In another aspect, the present invention provides an apparatus for removing nitrogen from a cryogenic hydrocarbon composition comprising a nitrogen- and methane-containing liquid phase, the apparatus comprising: for removing nitrogen from a cryogenic hydrocarbon composition comprising a nitrogen- and methane-containing liquid phase, the apparatus comprising:

- a cryogenic feed line connected to a source of a cryogenic hydrocarbon composition comprising nitrogen and a methane-containing liquid phase;
- a nitrogen stripper column in fluid communication with the cryogenic feed line, said nitrogen stripper column comprising at least one internal stripping section positioned within the nitrogen stripper column and a sump space defined gravitationally below the stripping section;
- a nitrogen-stripped liquid discharge line comprising an intermediate depressurizer, in fluid communication with the sump space of the nitrogen stripper column arranged to receive a nitrogen-stripped liquid from the

sump space and to depressurize the nitrogen-stripped liquid, said intermediate depressurizer located on an interface between a stripping pressure side comprising the nitrogen stripper column and a flash pressure side;

- a liquid hydrocarbon product line arranged on the flash pressure side in communication with the intermediate depressurizer, to discharge a liquid hydrocarbon product stream produced from the nitrogen-stripped liquid;
- a process vapour line arranged on the flash pressure side in communication with the intermediate depressurizer, to receive a process vapour produced from the nitrogen-stripped liquid;
- a process compressor arranged in the process vapour line arranged to receive the process vapour and compress the process vapour to provide a compressed vapour at a process compressor discharge outlet of the process compressor, said process compressor being on said interface between the stripping pressure side and the flash pressure side;
- a bypass splitter, whereby an upstream side thereof is in fluid communication with the discharge outlet of the process compressor to receive the compressed vapour, and of which bypass splitter a first discharge side is in fluid communication with the nitrogen stripper column via a stripping vapour line and a second inlet system arranged at a level gravitationally below the stripping section and arranged to receive at least a stripping portion of said compressed vapour from the process compressor, and of which bypass splitter a second discharge side is in fluid communication with a vapour bypass line containing a non-stripping portion of the compressed vapour;

- a condenser arranged in fluid communication with the vapour bypass line to bring an intermediate vapour that comprises at least the non-stripping portion from the vapour bypass line, which condenser comprises a heat exchanging surface providing indirect heat exchange contact between the intermediate vapour and an auxiliary refrigerant stream;
- a discharge line in communication with both the condenser and with an overhead space of the nitrogen stripper column, and arranged to discharge a vapour fraction as off gas comprising an overhead vapour obtained from the overhead space of the nitrogen stripper column and a bypass portion comprising a non-condensed vapour from the intermediate vapour that has passed though the condenser; and
- a liquid recycle line on its upstream side in fluid communication with the condenser and on its downstream side in liquid communication with the liquid hydrocarbon product line;

wherein a bypass path extends between the bypass splitter and the discharge line, wherein the bypass path bypasses the at least one internal stripping section.

The invention will be further illustrated hereinafter, using examples and with reference to the drawing in which;

Fig. 1 schematically represents a process flow scheme representing a method and apparatus incorporating an embodiment of the invention; and

Fig. 2 schematically represents a process flow scheme representing a method and apparatus incorporating another embodiment of the invention.

In these figures, same reference numbers will be used to refer to same or similar parts. Furthermore, a single reference number will be used to identify a conduit or line as well as the stream conveyed by that line.

The present description concerns removal of nitrogen from a cryogenic hydrocarbon composition comprising a nitrogen- and methane-containing liquid phase. A least a first portion of the cryogenic hydrocarbon composition is fed to a nitrogen stripper column as a first nitrogen stripper feed stream. A nitrogen-stripped liquid is drawn from the nitrogen stripper column. A liquid hydrocarbon product stream and a process vapour are produced comprising at least a step of depressurizing the nitrogen-stripped liquid to a flash pressure. The process vapour is compressed, and selectively split into a stripping portion and a non-stripping portion. A stripping vapour stream comprising at least the stripping portion is passed into the nitrogen stripper column gravitationally below a stripping section positioned therein. An intermediate vapour, comprising at least the non-stripping portion of the compressed process vapour, is passed through a condenser whereby an excess liquid is formed from the intermediate vapour and whereby at least a bypass portion from the compressed vapour remains in vapour phase. A vapour fraction is discharged as off gas, comprising a discharge fraction of overhead vapour from the nitrogen stripper column and comprising at least the bypass portion from the compressed vapour which bypasses the stripping section positioned in the nitrogen stripper column. A liquid recycle portion comprises at least part of the excess liquid. At least part of the liquid recycle portion is returned to the liquid hydrocarbon product stream.

An advantage of splitting off the non-stripping portion, which contains the bypass portion from the compressed process vapour, and passing at least the bypass portion to the off gas whereby bypassing at least the stripping section positioned within the nitrogen stripper column, is that the nitrogen stripper column can be protected against excess flow of stripping vapour flowing through the stripping section. Such excess flow may cause disturbance of the equilibrium conditions. Thanks to passing the non-stripping portion through the condenser, it is avoided that valuable parts of the process vapour that are split off in the non-stripping portion, such as typically vaporous methane, are lost through the off gas but instead can be re-condensed and added to excess liquid, which is led back ultimately to the liquid hydrocarbon product stream.

The vapour fraction in the off gas generally has a heating value. Preferably, the cooling duty in the condenser is adjusted to regulate the heating value of the vapour fraction being discharged. The ability to regulate the heating value is advantagous allows to stabilize the heating value of the vapour fraction in the off gas against variation or fluctuations in the flow rate and/or the composition of the bypass portion from the compressed process vapour compared to the flow rate and/or composition of the overhead vapour from the nitrogen stripper column. Variations in both flow rate and compositions can be expected in an LNG plant when transiting from holding mode operation to loading mode operation. Not only is the vapour flow rate higher during loading mode, the composition is leaner as well (particularly containing more nitrogen). The ability to adjust the bypass portion as well as the cooling duty in the condenser both contribute to the ability to handle the additional vapour load during the loading mode.

The process vapour may comprise vaporous methane that has previously formed part of the raw liquefied product. Vaporous methane that has previously formed part of the raw liquefied product can be formed in an LNG liquefaction plant due to various reasons. During normal operation of a natural gas liquefaction facility, methane containing vapour is formed from the (raw) liquefied product in the form of:

- flash vapour resulting from flashing of the raw liquefied product during depressurizing; and
- boil-off gas resulting from thermal evaporation caused by heat added to the liquefied product, for instance in the form of heat leakage into storage tanks, LNG piping, and heat input from plant LNG pumps. During this mode of operation, known as holding mode operation, the storage tanks are being filled with the liquefied hydrocarbon product as it comes out of the plant without any transporter loading operations taking place at the same time. When in holding mode, the methane-containing vapours are generated on the plant side of the storage tanks.

The operation mode of an LNG plant while there are ongoing transporter loading operations (typically ship loading operations) is known as loading mode operation. During loading mode operation, boil-off gas is additionally produced on the ship side of the storage tanks, for instance due to initial chilling of the ship tanks; vapour displacement from the ship tanks; heat leakage through piping and vessels connecting the storage tanks and the ships, and heat input from LNG loading pumps.

The proposed solution may facilitate the handling of these vapours both during holding mode and loading mode operations. It combines the removal of nitrogen from the cryogenic hydrocarbon composition with re-condensation of excess vaporous methane. This forms an elegant solution in situations where little plant fuel is demanded, such as could be the case in an electrically driven plant using electric power from an external power grid.

While the process vapour may comprise one or both of flash vapour and boil-off gas, it is particularly suited for boil-off gas. The flow rate of boil-off gas is the most subject to variation in a typical LNG plant. Since the proposed solution allows for selectively stripping of the compressed vapour into stripping and non-stripping portions, it allows to selectively bypass the stripping section in the nitrogen stripper column with any process vapour in excess of what is needed as stripping vapour. This makes the proposed solution particularly suited to accommodate boil-off gas into the process vapour.

Figure 1 illustrates an apparatus comprising an embodiment of the invention. A cryogenic feed line 8 is in fluid communication with a nitrogen stripper column 20, via a first inlet system 21. A first feed line 10 connects the cryogenic feed line 8 with the first inlet system 21 of the nitrogen stripper column 20, optionally via an initial stream splitter 9 arranged between the cryogenic feed line 8 and the first feed line 10.

Upstream of the cryogenic feed line 8, a liquefaction system 100 may be provided. The liquefaction system 100 functions as a source of a cryogenic hydrocarbon composition. The liquefaction system 100 is in fluid communication with the cryogenic feed line 8 via a main depressurizing system 5, which communicates with the liquefaction system 100 via a raw liquefied product line 1. In the embodiment as shown, the main depressurizing system 5 consists of a dynamic unit, such as an expander turbine 6, and a static unit, such as a Joule Thomson valve 6, but other variants are possible. Preferably, but not necessarily, any compressor forming part of the hydrocarbon liquefaction process in the liquefaction system, particularly any refrigerant compressor, is driven by one or more electric motors, without being mechanically driven by any steam- and/or gas turbine. Such compressor may be driven exclusively by one or more electric motors.

The nitrogen stripper column 20 comprises an internal stripping section 24 positioned within the nitrogen stripper column 20. An overhead vapour discharge line 30 communicates with the nitrogen stripper column 20 via an overhead space 26 within the nitrogen stripper column 20. A nitrogen-stripped liquid discharge line 40 communicates with the nitrogen stripper column 20 via a sump space 28 within the nitrogen stripper column 20 gravitationally below the stripping section 24.

The nitrogen stripper column 20 may comprise vapour/liquid contact-enhancing means to enhance component separation and nitrogen rejection. Depending on the tolerable amount of nitrogen in the nitrogen stripped liquid and the amount of nitrogen in the cryogenic feed line 8, between 2 and 8 theoretical stages may typically be needed in total. In one particular embodiment, 4 theoretical stages were required. Such contact-enhancing means may be provided in the form of trays and/or packing, in the form of either structured or non-structured packing. At least part of the vapour/liquid contact-enhancing means suitably forms part of the internal stripping section 24.

An intermediate depressurizer 45 is arranged in the nitrogen-stripped liquid discharge line 40, and thereby fluidly connected to the nitrogen stripper column 20. The intermediate depressurizer 45 is functionally coupled to a level controller LC, which cooperates with the sump space 28 of the nitrogen stripper column 20.

The intermediate depressurizer 45 is located on an interface between a stripping pressure side comprising the nitrogen stripper column 20, and a flash pressure side. The flash pressure side comprises a liquid hydrocarbon product line 90, arranged to discharge a liquid hydrocarbon product stream produced from the nitrogen-stripped liquid 40, and a process vapour line 60, arranged to receive a process vapour produced from the nitrogen-stripped liquid 40. In the embodiment as shown, the flash pressure side furthermore comprises a cryogenic storage tank 210 connected to the liquid hydrocarbon product line 90 for storing the liquid hydrocarbon product stream, an optional boil-off gas supply line 230, and an optional end flash separator 50.

If such end flash separator 50 is provided, such as is the case in the embodiment of Figure 1, it may be configured in fluid communication with the nitrogen stripper column 20 via the intermediate depressurizer 45 and the nitrogen-stripped liquid discharge line 40. The end flash separator 50 may then be connected to the cryogenic storage tank 210 via the liquid hydrocarbon product line 90. A cryogenic pump 95 may be present in the liquid hydrocarbon product line 90 to assist the transport of the liquid hydrocarbon product to the cryogenic storage tank 210.

If the initial stream splitter 9 is provided, the cryogenic feed line 8 is also connected to at least one of the group consisting of: the nitrogen-stripped liquid discharge line 40, the liquid hydrocarbon product line 90 and the process vapour line 60. To this end, a second feed line 11 is connected at an upstream side thereof to the optional initial splitter 9. This second feed line 11 bypasses the nitrogen stripper column 20. A bypass stream flow control valve 15 is arranged in the second feed line 11. The bypass stream flow control valve is functionally connected to a flow controller FC provided in the first feed line 10. Suitably, the second feed line 11 feeds into the optional end flash separator 50.

A benefit of the optional second feed line 11 and the optional initial splitter 9 is that the nitrogen stripper column 20 can be sized smaller than in the case that the cryogenic feed line 8 and the first feed line 10 are directly connected without a splitter such that all of the cryogenic hydrocarbon composition is let into the nitrogen stripper column 20 via the first inlet system 21.

The process vapour line 60, as shown in the embodiment of Fig. 1, may be connected to the optional end flash separator 50 via a flash vapour line 64 and flash vapour flow control valve 65, as well as to the cryogenic storage tank 210 via the optional boil-off gas supply line 230. An advantage of the latter connection is that it allows for re-condensing of at least part of the boil-off gas from the cryogenic storage tank 210 by means of a condenser, which will be further discussed herein below.

Also configured on the interface between the stripping pressure side and the flash pressure side, is a process compressor 260. Preferably, the process compressor 260 is driven by an electric motor. The process compressor 260 is arranged in the process vapour line 60 to receive the process vapour and to compress the process vapour. A compressed vapour discharge line 70 is fluidly connected with a process compressor discharge outlet 261 of the process compressor 260. Suitably, the process compressor 260 is provided with anti-surge control and a recycle cooler which is used when the process compressor is on recycle and during start-up (not shown in the drawing).

A stripping vapour line 71 is in fluid communication with the nitrogen stripper column 20 via a second inlet system 23 configured at a level gravitationally below the stripping section 24 and preferably above the sump space 28. The stripping vapour line 71 is connected to the compressed vapour discharge line 70 via a bypass splitter 79. A stripping vapour valve 75 is provided in the stripping vapour line 71.

Optionally, an external stripping vapour supply line 74 is provided in fluid communication with the second inlet system 23 of the nitrogen stripper column 20. In one embodiment, as shown in Fig. 1, the optional external stripping vapour supply line 74 connects to the compressed vapour discharge line 70. An external stripping vapour flow control valve 73 is provided in the optional external stripping vapour supply line 74. In one embodiment, the optional external stripping vapour supply line 74 is suitably connected to a hydrocarbon vapour line in, or upstream of, the liquefaction system 100.

The bypass splitter 79 is also in fluid communication with a condenser via at least a vapour bypass line 76. A vapour bypass control valve 77 is preferably provided in the vapour bypass line 76. The vapour bypass line 76 contains a non-stripping portion of the compressed vapour from the compressed vapour discharge line 70. The condenser can be any type of indirect heat exchanger in fluid communication with the bypass splitter 79 via the vapour bypass line 76. Such condenser is advantageously utilized to re-condense at least part of compressed process vapour from the compressed vapour discharge line 70.

Figure 1 shows a convenient embodiment wherein the condenser is provided in the form of an overhead condenser 35 external to the nitrogen stripper column 20. The overhead condenser 35 is arranged in fluid communication with both the overhead vapour discharge line 30 and the vapour bypass line 76, to partially condense an intermediate vapour stream that contains the non-stripping portion from the vapour bypass line 76 in addition to any overhead vapour being discharged from the nitrogen stripper column 20. The condenser comprises a heat exchanging surface that provides indirect heat exchange contact between the intermediate vapour and the auxiliary refrigerant stream 132, whereby heat can pass from the intermediate vapour to the auxiliary refrigerant stream 132 at a cooling duty. An auxiliary refrigerant stream flow control valve 135 is provided in the auxiliary refrigerant line 132.

In the embodiment of Figure 1, the vapour bypass line 76 suitably extends along a bypass path extending between the bypass splitter 79 and the overhead vapour discharge line 30 on an upstream side of the overhead condenser 35. The bypass path extends between the bypass splitter 79 and the overhead vapour discharge line 30 and/or the vapour fraction discharge line 80. The bypass path does not pass through the internal stripping section 24 in the nitrogen stripper column 20. This way it can be avoided that the non-stripping portion passes through the internal stripping section 24, which helps to avoid disturbing the equilibrium in the nitrogen stripper column 20.

Still referring to Figure 1, an overhead separator 33 is arranged on a downstream side of the overhead vapour discharge line 30. The overhead vapour discharge line 30 discharges into the overhead separator 33. The overhead separator 33 is arranged to separate any, non-condensed, vapour fraction from any condensed fraction of the overhead vapour.

A vapour fraction discharge line 80 is arranged to discharge the vapour fraction mentioned above. The vapour fraction discharge line 80 is in fluid communication with both the condenser and with the overhead space 26 of the nitrogen stripper column 20. In embodiments such as the one of Figure 1, wherein the intermediate vapour contains both the overhead vapour and the non-stripping vapour the vapour fraction discharge line 80 is inherently in communication with both the condenser and with the overhead space 26 of the nitrogen stripper column 20. The bypass path in this embodiment extends to the vapour fraction discharge line 80.

A benefit of the vapour bypass line 76 is that at times when there is an excess of process vapour, this can be processed together with the off gas in the vapour fraction discharge line 80 without upsetting the material balance in the nitrogen stripper column 20.

The condenser is also in fluid communication with a liquid recycle line 13. The liquid recycle line 13 is in liquid communication with the liquid hydrocarbon product line 90. Liquid communication means that the liquid recycle line 13 is connected to any suitable location from where at least a part of a liquid recycle portion can flow into the liquid hydrocarbon product line 90 while staying in the liquid phase. Thus, the liquid recycle line 13 may for instance be connected directly to one or more selected from the group consisting of: the nitrogen stripper column 20, the cryogenic feed line 8, the first feed line 10, the optional second feed line 11, the nitrogen-stripped liquid discharge line 40, the optional end flash separator 50 and the liquid hydrocarbon product line 90. A recycle valve 14 is configured in the liquid recycle line 13.

Optionally, the nitrogen stripper column 20 comprises an internal rectifying section 22 in addition to the internal stripping section 24. The internal rectifying section 22 is positioned within the nitrogen stripper column 20, gravitationally higher than the stripping section 24. The overhead space 26 is preferably defined gravitationally above the rectifying section 22. The first inlet system 21 is provided gravitationally between the internal rectifying section 22 and the internal stripping section 24. The overhead space 26 is gravitationally above the rectifying section 22.

The optional internal rectifying section 22 may comprise vapour/liquid contact-enhancing means similar to the internal stripping section 24, to further enhance component separation and nitrogen rejection.

A reflux system may be arranged to allow at least a reflux portion 36 of the condensed fraction into the nitrogen stripper column 20 at a level above the rectifying section 22. In the embodiment of Figure 1, the reflux system comprises a condensed fraction discharge line 37 fluidly connected to a lower part of the overhead separator 33, an optional reflux pump 38 provided in the condensed fraction discharge line 37, and a condensed fraction splitter 39. The condensed fraction splitter 39 fluidly connects the condensed fraction discharge line 37 with the nitrogen stripper column 20, via a reflux portion line 36 and a reflux inlet system 25, and with the liquid recycle line 13. An optional reflux flow valve 32 functionally controlled by a reflux flow controller (not shown) may preferably be provided in the reflux portion line 36.

In embodiments wherein the nitrogen stripper column 20 comprises the optional internal rectifying section 22, the liquid recycle line 13 is preferably in liquid communication with the liquid hydrocarbon product line 90 via a recycle path that does not pass through the rectifying section 22 if it is provided. This way the liquid recycle line 13 helps to avoid feeding too much liquid onto the rectifying section 22 and to avoid passing the recycle liquid through the rectifying section 22. This is beneficial to avoid disturbing the equilibrium in the nitrogen stripper column 20.

A cooling duty controller 34 may be provided to control the cooling duty, being the rate at which heat passes from the intermediate vapour to the auxiliary refrigerant stream. Suitably, the cooling duty controller 34 is configured to control the cooling duty in response to an indicator of heating value of the off gas relative to a demand for heating power. In the embodiment as shown, the cooling duty controller 34 is embodied in the form of a pressure controller PC and the auxiliary refrigerant stream flow control valve 135, which are functionally coupled to each other.

A combustion device 220 is suitably arranged on a downstream end of the vapour fraction discharge line 80, to receive at least a fuel portion of the vapour fraction in the vapour fraction discharge line 80. The combustion device may comprise multiple combustion units, and/or it may include for example one or more of a furnace, a boiler, an incinerator, a dual fuel diesel engine, or combinations thereof. A boiler and a duel fuel diesel engine may be coupled to an electric power generator.

The amount of methane in the off gas can be controlled to meet a specific demand for methane. This renders the off gas suitable for use as fuel gas stream, preferably at a fuel gas pressure not higher than the stripping pressure, even in circumstances where the demand for heating value is variable.

A vapour recycle line 87 is optionally configured to receive at least a vaporous recycle portion of the vapour from the overhead discharge line 30. The vapour recycle line 87 bypasses the nitrogen stripper column 20, and feeds back into at least one of the group consisting of: the liquid hydrocarbon product line 90 and the process vapour line 60. A vapour recycle flow control valve 88 is preferably provided in the vapour recycle line 87. A benefit of the proposed vapour recycle line 87 is that it allows for selectively increasing of the nitrogen content in the liquid hydrocarbon product stream 90. If the optional end flash separator 50 is provided, the vapour recycle line 87 suitably feeds into the end flash separator 50.

Suitably, the configuration of the optional vapour recycle line 87 comprises an optional vapour fraction splitter 89, which may be provided in the vapour fraction line 80, allowing controlled fluid communication between the vapour fraction line 80 and the vapour recycle line 87.

A cold recovery heat exchanger 85 may be provided in the vapour fraction discharge line 80, to preserve the cold vested in the vapour fraction 80 by heat exchanging against a cold recovery stream 86 prior to feeding the vapour fraction 80 to any combustion device.

In one embodiment, the cold recovery stream 86 may comprise or consist of a side stream sourced from the hydrocarbon feed stream in the hydrocarbon feed line 110 of the liquefaction system 100. The resulting cooled side stream may for instance be combined with the cryogenic hydrocarbon composition in the cryogenic feed line 8. Thus, the cold recovery heat exchanging in the cold recovery heat exchanger 85 supplements the production rate of the cryogenic hydrocarbon composition. In another embodiment, the cold recovery stream 86 may comprise or consist of the overhead vapour in the overhead vapour discharge line 30, preferably in the part of the overhead vapour discharge line 30 where through the overhead vapour is passed from the nitrogen stripper column 20 to the overhead condenser 35. Herewith the duty required from the auxiliary refrigerant stream 132 in the overhead condenser 35 would be reduced.

The liquefaction system 100 in the present specification has so far been depicted very schematically. It can represent any suitable hydrocarbon liquefaction system and/or process, in particular any natural gas liquefaction process producing liquefied natural gas, and the invention is not limited by the specific choice of liquefaction system. Examples of suitable liquefaction systems employ single refrigerant cycle processes (usually single mixed refrigerant - SMR -

processes, such as PRICO described in the paper "LNG Production on floating platforms" by K R Johnsen and P Christiansen, presented at Gastech 1998 (Dubai), but also possible is a single component refrigerant such as for instance the BHP-cLNG process also described in the afore-mentioned paper by Johnsen and Christiansen); double refrigerant cycle processes (for instance the much applied Propane-Mixed-Refrigerant process, often abbreviated C3MR, such as described in for instance US Patent 4,404,008, or for instance double mixed refrigerant - DMR - processes of which an example is described in US Patent 6,658,891, or for instance two-cycle processes wherein each refrigerant cycle contains a single component refrigerant); and processes based on three or more compressor trains for three or more refrigeration cycles of which an example is described in US Patent 7,114,351.

Other examples of suitable liquefaction systems are described in: US Patent 5,832,745 (Shell SMR); US Patent 6,295,833; US Patent 5,657,643 (both are variants of Black and Veatch SMR); US Pat. 6,370,910 (Shell DMR). Another suitable example of DMR is the so-called Axens LIQUEFIN process, such as described in for instance the paper entitled "LIQUEFIN: AN INNOVATIVE PROCESS TO REDUCE LNG COSTS" by P-Y Martin *et al*, presented at the 22nd World Gas Conference in Tokyo, Japan (2003). Other suitable three-cycle processes include for example US Pat. 6,962,060; WO 2008/020044; US Pat. 7,127,914; DE3521060A1; US Pat. 5,669,234 (commercially known as optimized cascade process); US Pat. 6,253,574 (commercially known as mixed fluid cascade process); US Pat. 6,308,531; US application publication 2008/0141711; Mark J. Roberts *et al* "Large capacity single train AP-

X(TM) Hybrid LNG Process”, Gastech 2002, Doha, Qatar (13-16 October 2002). These suggestions are provided to demonstrate wide applicability of the invention, and are not intended to be an exclusive and/or exhaustive list of possibilities.

Preferably, but not necessarily, any compressor forming part of the hydrocarbon liquefaction process in the liquefaction system, particularly any refrigerant compressor, is driven by one or more electric motors, without being mechanically driven by any steam- and/or gas turbine. Such compressor may be driven exclusively by one or more electric motors. Not all examples listed above employ electric motors as refrigerant compressor drivers. It will be clear that any drivers other than electric motors can be replaced for an electric motor to enjoy the most benefit of the present invention.

An example wherein in the liquefaction system 100 is based on, for instance C3MR or Shell DMR, is briefly illustrated in Figure 2. It employs a cryogenic heat exchanger 180, in this case in the form of a coil wound heat exchanger comprising lower and upper hydrocarbon product tube bundles (181 and 182, respectively), lower and upper LMR tube bundles (183 and 184, respectively) and an HMR tube bundle 185.

The lower and upper hydrocarbon product tube bundles 181 and 182 fluidly connect the raw liquefied product line 1 with a hydrocarbon feed line 110. At least one refrigerated hydrocarbon pre-cooling heat exchanger 115 may be provided in the hydrocarbon feed line 110 upstream of the cryogenic heat exchanger 180.

A main refrigerant, in the form of a mixed refrigerant, is provided in a main refrigerant circuit 101. The main refrigerant circuit 101 comprises a spent refrigerant line 150, connecting the cryogenic heat exchanger 180 (in this case a shell side 186 of the cryogenic heat exchanger 180) with a main suction end of a main refrigerant compressor 160, and a compressed refrigerant line 120 connecting a main refrigerant compressor 160 discharge outlet with an MR separator 128. One or more heat exchangers are provided in the compressed refrigerant line 120, including in the present example at least one ambient heat exchanger 124 and at least one refrigerated main refrigerant pre-cooling heat exchanger 125. The MR separator 128 is in fluid connection with the lower LMR tube bundle 183 via a light refrigerant fraction line 121, and with the HMR tube bundle via a heavy refrigerant fraction line 122.

The at least one refrigerated hydrocarbon pre-cooling heat exchanger 115 and the at least one refrigerated main refrigerant pre-cooling heat exchanger 125 are refrigerated by a pre-cooling refrigerant (via lines 127 and 126, respectively). The same pre-cooling refrigerant may be shared from the same pre-cooling refrigerant cycle. Moreover, the at least one refrigerated hydrocarbon pre-cooling heat exchanger 115 and the at least one refrigerated main refrigerant pre-cooling heat exchanger 125 may be combined into one pre-cooling heat exchanger unit (not shown). Reference is made to US Pat. 6,370,910 as a non-limiting example.

The optional external stripping vapour supply line 74 (if provided) may suitably be connected to the hydrocarbon feed line 110, either at a point upstream of the at least one refrigerated hydrocarbon pre-cooling heat exchanger 115, downstream of the at least one refrigerated hydrocarbon pre-cooling heat exchanger 115, or (for instance possible if two or more refrigerated hydrocarbon pre-cooling heat exchangers are provided) between two consecutive refrigerated hydrocarbon pre-cooling heat exchangers, to be sourced with a part of the hydrocarbon feed stream from the hydrocarbon feed line 110.

At a transition point between the upper (182, 184) and lower (181, 183) tube bundles, the HMR tube bundle 185 is in fluid connection with an HMR line 141 in which an HMR control valve 144 is configured. The HMR line 141 is in fluid communication with the shell side 186 of the cryogenic heat exchanger 180 and, via said shell side 186 and in heat exchanging arrangement with each of one of the lower hydrocarbon product tube bundle 181 and the lower LMR tube bundle 183 and the HMR tube bundle 185, with the spent refrigerant line 150.

Above the upper tube bundles 182 and 184, near the top of the cryogenic heat exchanger 180, the LMR tube bundle 184 is in fluid connection with an LMR line 131. A first LMR return line 133 establishes fluid communication between the LMR line 131 and the shell side 186 of the cryogenic heat exchanger 180. An LMR control valve 134 is configured in the first LMR return line 133. The first LMR return line 133 is in fluid communication with the spent refrigerant line 150, via said shell side 186 and in heat exchanging arrangement with each of one of the upper and lower hydrocarbon product tube bundles 182 and 181, and each one of the LMR tube bundles 183 and 184, and the HMR tube bundle 185.

Figure 2 reveals one possible source of the auxiliary refrigerant. The LMR line 131 is split into the auxiliary refrigerant line 132 and the first LMR return line 133. A second LMR return line 138 on an upstream end thereof fluidly connects with the auxiliary refrigerant line 132 via the overhead condenser (for example the overhead condenser 35 of Figure 1, or an integrated internal overhead condenser 235 as depicted in Figure 2), and on a downstream end the second LMR return line 138 ultimately connects with the spent refrigerant line 150, suitably via the first HMR line 141.

The line up around the nitrogen stripper column 20 in Figure 2 is similar to the one shown in Figure 1 and will not be set forth in detail again. Optional lines including the optional second feed line 11, the optional external stripping vapour supply line 74, and the optional vapour recycle line 87 may be provided but have not been reproduced in Figure 2 for purpose of clarity.

One difference to be noted, however, between the embodiment of Figure 2 with that of Figure 1 is that the overhead condenser 35, the overhead separator 33 and the reflux system have been embodied in the form of the integrated internal overhead condenser 235, which is internally configured within the overhead space 26 in the nitrogen stripper column 20. Such internal overhead condenser 235, as such, is known in the art. The liquid recycle line 13 is provided in liquid communication with a partial liquid draw off tray 27 provided inside the nitrogen stripper column 20 gravitationally above the rectifying section 22 and below the internal overhead condenser 235. The partial liquid draw off tray 27 functions equivalently to the condensed fraction splitter 39 of Figure 1.

Regardless of whether in the form of the (external) overhead condenser 35 or the internal overhead consenser 235, the condenser is preferably arranged in fluid communication with both the vapour bypass line 76 and the overhead space 26 of the nitrogen stripper column 20, whereby the intermediate vapour passing through the condenser preferably comprises both the non-stripping portion from the vapour bypass line 76 and the overhead vapour obtained from the overhead space 26 of the nitrogen stripper column 20.

The apparatus and method for removing nitrogen from a cryogenic hydrocarbon composition comprising a nitrogen- and methane-containing liquid phase may be operated as follows.

A cryogenic hydrocarbon composition 8 comprising a nitrogen- and methane-containing liquid phase is provided, preferably at an initial pressure of between 2 and 15 bar absolute (bara), and preferably at a temperature lower than -130 °C.

The cryogenic hydrocarbon composition 8 may be obtained from natural gas or petroleum reservoirs or coal beds. As an alternative the cryogenic hydrocarbon composition 8 may also be obtained from another source, including as an example a synthetic source such as a Fischer-Tropsch process. Preferably the cryogenic hydrocarbon composition 8 comprises at least 50 mol% methane, more preferably at least 80 mol% methane.

In typical embodiments, the temperature of lower than -130 °C can be achieved by passing a hydrocarbon feed stream 110 through the liquefaction system 100. In such a liquefaction system 100, the hydrocarbon feed stream 110 comprising a hydrocarbon-containing feed vapour may be heat exchanged, for example in the cryogenic heat exchanger 180, against a main refrigerant stream, thereby liquefying the feed vapour of the feed stream to provide a raw liquefied stream within the raw liquefied product line 1. The desired cryogenic hydrocarbon composition 8 may then be obtained from the raw liquefied stream 1.

The main refrigerant stream may be generated by cycling the main refrigerant in the main refrigerant circuit 101, whereby spent refrigerant 150 is compressed in the main refrigerant compressor 160 to form a compressed refrigerant 120 out of the spent refrigerant 150. Heat is removed from the compressed refrigerant discharged from the main refrigerant compressor 160 is via the one or more heat exchangers that are provided in the compressed refrigerant line 120. This results in a partially condensed compressed refrigerant, which is phase separated in the MR separator 128 into a light refrigerant fraction 121 consisting of the vaporous constituents of the partially condensed compressed refrigerant, and a heavy refrigerant fraction 122 consisting of the liquid constituents of the partially condensed compressed refrigerant.

The light refrigerant fraction 121 is passed via successively the lower LMR bundle 183 and the upper LMR bundle 184 through the cryogenic heat exchanger 180, while the heavy refrigerant fraction 122 is passed via the HMR bundle 185 through the cryogenic heat exchanger 180 to the transition point. While passing through these respective tube bundles, the respective light- and heavy refrigerant fractions are cooled against the light and heavy refrigerant fractions that are evaporating in the shell side 186 again producing spent refrigerant 150 which completes the cycle. Simultaneously, the hydrocarbon feed stream 110 passes through the cryogenic heat exchanger 180 via successively the lower hydrocarbon bundle 181 and the upper hydrocarbon bundle 182 and is being liquefied and sub-cooled against the same evaporating light and heavy refrigerant fractions.

Depending on the source, the hydrocarbon feed stream 110 may contain varying amounts of components other than methane and nitrogen, including one or more non-hydrocarbon components other than water, such as CO_2, Hg, H_2S and other sulphur compounds; and one or more hydrocarbons heavier than methane such as in particular ethane, propane and butanes, and, possibly lesser amounts of pentanes and aromatic hydrocarbons. Hydrocarbons with a molecular mass of at least that of propane may herein be referred to as C_3+ hydrocarbons, and hydrocarbons with a molecular mass of at least that of ethane may herein be referred to as C_2+ hydrocarbons.

If desired, the hydrocarbon feed stream 110 may have been pre-treated to reduce and/or remove one or more of undesired components such as CO_2 and H_2S, or have undergone other steps such as pre-pressurizing or the like. Such steps are well known to the person skilled in the art, and their mechanisms are not further discussed here. The composition of the hydrocarbon feed stream 110 thus varies depending upon the type and location of the gas and the applied pre-treatment(s).

The raw liquefied stream 1 may comprise between from 1 mol% to 5 mol% nitrogen, be at a raw temperature of between from -165 °C to -120 °C and typically at a liquefaction pressure of between from 15 bara to 120 bara. In many cases, the raw temperature may be between from -155 °C to -140 °C. Within this more narrow range the cooling duty needed in the liquefaction system 100 is lower than when lower temperatures are desired, while the amount of sub-cooling at the pressure of above 15 bara is sufficiently high to avoid excessive production of flash vapours upon depressurizing to between 1 and 2 bara.

The cryogenic hydrocarbon composition 8 may be obtained from the raw liquefied stream 1 by main depressurizing the raw liquefied stream 1 from the liquefaction pressure to the initial pressure. A first nitrogen stripper feed stream 10 is derived from the cryogenic hydrocarbon composition 8, and fed into the nitrogen stripper column 20 at a stripping pressure via the first inlet system 21.

The stripping pressure is usually equal to or lower than the initial pressure. The stripping pressure in preferred embodiments is selected in a range of between 2 and 15 bar absolute. Preferably, the stripping pressure is at least 4 bara, because with a somewhat higher stripping pressure the stripping vapour in stripping vapour line 71 can benefit from some additional enthalpy (in the form of heat of compression) that is added to the process stream 60 in the process compressor 260. Preferably, the stripping pressure is at most 8 bara in order to facilitate the separation efficiency in the nitrogen stripper column 20. Moreover, if the stripping pressure is within a range of between from 4 to 8 bara, the off gas in the vapour fraction line 80 can readily be used as so-called low pressure fuel stream without a need to further compress.

In one example, the raw temperature of the raw liquefied stream 1 was -161 °C while the liquefaction pressure was 55 bara. The main depressurization may be effected in two stages: first a dynamic stage using the expansion turbine 6 to reduce the pressure from 55 bara to about 10 bara, followed by a further depressurization in a static stage using the Joule Thomson valve 7 to a pressure of 7 bara. The stripping pressure in this case was assumed to be 6 bara.

An overhead vapour stream 30 is obtained from the overhead space 26 of the nitrogen stripping column 20. A vapour fraction 80 obtained from the overhead vapour stream 30, and comprising a discharge fraction of the overhead vapour 30, is discharged as off gas. Suitably, at least a fuel portion of the vapour fraction 80 is passed to the combustion device 220 at a fuel gas pressure that is not higher than the stripping pressure.

A nitrogen-stripped liquid 40 is drawn from the sump space 26 of the nitrogen stripper column 20. The temperature of the nitrogen-stripped liquid 40 is typically higher than that of the first nitrogen stripper feed stream 10. Typically, it is envisaged that the temperature of the nitrogen-stripped liquid 40 is higher than that of the first nitrogen stripper feed stream 10 and between -140 °C and -80 °C, preferably between -140 °C and -120 °C.

The nitrogen-stripped liquid 40 is then depressurized, preferably employing the intermediate depressurizer 45, to a flash pressure that is lower than the stripping pressure, suitably in a range of between from 1 and 2 bar absolute. Preferably, the flash pressure lies in a range of between from 1.0 and 1.4 bara. With a somewhat higher differential between the flash pressure and the stripping pressure, the stripping vapour in stripping vapour line 71 can benefit from some additional heat of compression that is added to the process stream 60 in the process compressor 260.

The intermediate depressurizer 45 may be controlled by the level controller LC, set to increase the flow rate through the intermediate depressurizer if the level of liquid accumulated in the sump space 26 of the nitrogen stripper column 20 increases above a target level. As a result of the depressurization, the temperature is generally lowered to below -160 °C. The liquid hydrocarbon product stream 90 that is produced hereby can typically be kept at an atmospheric pressure in an open insulated cryogenic storage tank.

Process vapour 60 is produced as well. The process vapour 60 may comprise flash vapour 64 that is often generated upon the depressurization of the nitrogen-stripped liquid 40 and/or depressurization of a bypass feed stream 11 (further discussed later herein below).

The first nitrogen stripper feed stream 10 comprises a first portion of the cryogenic hydrocarbon composition 8. It may contain all of the cryogenic hydrocarbon composition 8, but in practice it is preferred to split the cryogenic hydrocarbon composition 8 into the first portion 10 and a second portion 11 having the same composition and phase as the first portion 10. The second portion is preferably diverted, in form of the bypass feed stream, from the stripping pressure side to a suitable location on the flash pressure side.

The split ratio, defined as the flow rate of the second portion relative to the flow rate of the cryogenic hydrocarbon composition in the cryogenic hydrocarbon composition line 8, may be controlled using the bypass stream flow control valve 15. This bypass stream flow control valve 15 may be controlled by the flow controller FC to maintain a predetermined target flow rate of the first nitrogen stripper feed stream 10 into the nitrogen stripper column 20. The flow controller FC will increase the open fraction of the bypass stream flow control valve 15 if there is a surplus flow rate that exceeds the target flow rate, and decrease the open fraction if there is a flow rate deficit compared to the target flow rate.

As a general guideline, the split ratio may advantageously be selected between 50 % and 95 %. The lower values are typically recommended for higher content of nitrogen in the cryogenic hydrocarbon composition, while higher values are preferred for lower content of nitrogen. In one example, the content of nitrogen in the cryogenic hydrocarbon composition 8 was 3.0 mol% whereby the selected split ratio was 75%.

The second portion originating from the initial stream splitter 9 is also be depressurized to said flash pressure, before subsequently feeding it into at least one of the group consisting of: the nitrogen-stripped liquid discharge line 40, the liquid hydrocarbon product line 90 and the process vapour line 60; while bypassing the nitrogen stripper column 20. Suitably the optional second portion is passed into the optional end flash separator 50.

The process vapour 60 may comprise boil-off gas. Boil-off gas 230 typically results from adding of heat to the liquid hydrocarbon product stream 90 whereby a part of the liquid hydrocarbon product stream 90 evaporates to form the boil-off gas. In a typical LNG plant the generation of boil-gas can exceed the flow rate of flash vapour by multiple times, particularly during operating the plant in so-called loading mode, and hence it is an important benefit to not only re-condense the flash vapour but to re-condense the boil-off gas as well, if there is not enough on-site demand for heating power to use all of the methane contained in the boil-off gas.

In order to facilitate transferring of the boil-off gas to the process vapour stream 60, preferably the optional boil-off gas supply line 230 connects a vapour space in the cryogenic storage tank 210 with the process vapour line 60. In order to facilitate transferring the flash vapour 64 to the process vapour stream 60, and to further denitrogenate the liquid hydrocarbon product stream 90, preferably, the nitrogen-stripped liquid after its depressurization is fed into the optional end flash separator where it is phase separated at a flash separation pressure into the liquid hydrocarbon product stream 90 and the flash vapour 64. The flash separation pressure is equal to or lower than the flash pressure, and suitably lies in the range of between from 1 to 2 bar absolute into the liquid hydrocarbon product stream 90 and the flash vapour 64. In one embodiment the flash separation pressure is envisaged to be 1.05 bara.

The process vapour 60 is compressed to at least the stripping pressure, thereby obtaining a compressed vapour stream 70. A stripping vapour stream 71 is obtained from the compressed vapour stream 70, and passed into the nitrogen stripper column 20 via the second inlet system 23. This stripping vapour can percolate upward through the stripping section 23 in contacting counter current with liquids percolating downward through the stripping section 23.

If the external stripping vapour supply line 74 is provided in fluid communication with the second inlet system 23, an external stripping vapour may selectively be fed into the nitrogen stripper column 20 via the second inlet system 23. Herewith major disruption of the nitrogen stripper column 20 may be avoided, for instance, in case the process compressor 260 is not functioning to provide the compressed vapour stream 70 in sufficient amounts.

Obtaining of the stripping vapour stream 71 from the compressed vapour stream 70 involves selectively splitting the compressed vapour stream 70 into a stripping portion and a non-stripping portion. The non-stripping portion comprises a bypass portion of the compressed vapour, which bypass portion may herein below also be referred to as vapour bypass portion. It does not contain the stripping portion. The stripping vapour stream 71 contains at least the stripping portion.

The selective injection may be controlled using the vapour bypass control valve 77. Suitably, the vapour bypass control valve 77 is controlled by a pressure controller on the compressed vapour line 70, which is set to increase the open fraction of the vapour bypass control valve 77 in response to an increasing pressure in the compressed vapour line 70. It is envisaged that the flow rate of the vapour bypass portion that is allowed to flow through the vapour bypass line 76 into the overhead vapour stream 30 is particularly high during so-called loading mode at which time usually the amount of boil-off gas is much higher than in is usually the case during so-called holding mode. Preferably, the vapour bypass control valve 77 is fully closed during normal operation in holding mode.

A partially condensed intermediate stream is formed from an intermediate vapour by passing the intermediate vapour through the condenser. The intermediate vapour that comprises at least the non-stripping portion of the compressed vapour. In preferred embodiments, such as illustrated in Figure 1, the intermediate vapour also contains the overhead vapour 30. This may be achieved by selectively injecting the non-stripping portion of the compressed vapour into the overhead vapour stream 30, thereby forming the intermediate vapour. The forming of the partially condensed intermediate stream suitably involves indirectly heat exchanging the intermediate vapour against the auxiliary refrigerant stream 132 and partially condensing the intermediate vapour, whereby heat is passed from the intermediate vapour to the auxiliary refrigerant stream 132 at a selected cooling duty. The resulting partially condensed intermediate stream comprises a condensed fraction containing an excess liquid, and a vapour fraction. The vapour fraction contains the bypass portion from the compressed vapour, which remains in the vapour phase throughout the partially condensing.

The condensed fraction is separated from the vapour fraction in the overhead separator 33, at a separation pressure that may be lower than the stripping pressure, and preferably lies in a range of between 2 and 15 bar absolute. The vapour fraction is discharged via the vapour fraction discharge line 80 as off gas. It contains a discharge fraction of the overhead vapour obtained from the overhead space 26 of the nitrogen stripper column 20 as well as at least the vapour bypass portion. The condensed fraction is discharged from the overhead separator 33 into a reflux system, for instance via the condensed fraction discharge line 37.

This way, from the selective splitting of the compressed vapour in the stripping and non-stripping portions all the way to the discharging of the bypass portion in the vapour fraction of the off gas, the bypass portion bypasses the at least one internal stripping section 24. In other words, on the route from the bypass splitter 79 to the overhead vapour discharge line 30 and/or the vapour fraction discharge line 80 the bypass portion does not pass through the at least one internal stripping section 24. Herewith it is achieved that any compressed vapour in the compressed vapour line 70 in excess of the amount of stripping vapour consumed during normal operation of the nitrogen stripper column 20 in equilibrium, is diverted around the stripping section 24 so that the equilibrium in the stripping within the nitrogen stripper column 20 is not disturbed. In preferred embodiments, the bypass portion bypasses not only the stripping section 24 but the entire nitrogen stripper column 20, such as is shown in the embodiment of Figure 1.

At least part of the condensed fraction discharged from the overhead separator 33 is led into the liquid recycle line 13 to form a liquid recycle portion. The recycle valve 14 may suitably be controlled using a flow controller provided in the condensed fraction discharge line 37 and/or a level controller provided on the overhead separator 33. The liquid recycle portion contains at least part of the excess liquid. At least part of liquid recycle portion is returned to the liquid hydrocarbon product stream, while keeping this at least part in liquid phase. This may be done by feeding the liquid recycle portion into at least one of the group consisting of: the nitrogen stripper column 20, the cryogenic hydrocarbon composition 8, the first nitrogen stripper feed stream 10, the optional bypass feed stream 11, the nitrogen-stripped liquid 40, the optional end flash separator 50 and the liquid hydrocarbon product stream 90.

The condenser, which in the embodiment of Figure 1 is embodied in the form of the overhead condenser 35, thus allows for re-condensation of vaporous methane that has previously formed part of the raw liquefied product 1 (or the cryogenic hydrocarbon composition 8), by adding any such vaporous methane containing stream to the (compressed) process vapour stream. Preferably, the methane is condensed to the extent that it is in excess of a target amount of methane in the discharged vapour fraction 80. Once forming part of the process vapour 60 or compressed process vapour 70, the vaporous methane can find its way to the heat exchanging with the auxiliary refrigerant 132 by which it is selectively condensed out of the overhead vapour 30 from the nitrogen stripper column 20, while allowing the majority of the nitrogen to be discharged with the off gas. Herewith it becomes possible to remove sufficient nitrogen from the cryogenic hydrocarbon composition 8 to produce a liquid hydrocarbon product stream 90 within a desired maximum specification of nitrogen content, while as the same time not producing more heating capacity in the off gas than needed.

The vapour fraction 80 in the off gas generally has a heating value. The heating value of the vapour fraction 80 being discharged is suitably regulated by adjusting the cooling duty in the overhead condenser 35. This may be done by the cooling duty controller 34. By adjusting the cooling duty at which heat is passed from the overhead vapour to the auxiliary refrigerant stream, the relative amount of methane in the off gas can be regulated. As a result, the heating value of the discharged vapour fraction can be regulated to match with a specific demand of heating power. This renders the off gas suitable for use as fuel gas stream, even in circumstances where the demand for heating value is variable.

When the vapour fraction 80 is passed to and consumed by a combustion device 220 as fuel, the heating value may be regulated to match with an actual demand of heating power by the combustion device 220.

The heating value being regulated may be selected in accordance with the appropriate circumstances of the intended use of the off gas as fuel gas. The heating value may be determined in accordance with DIN 51857 standards. For many applications, the heating value being regulated may be proportional to the lower heating value (LHV; sometimes referred to as net calorific value), which may be defined as the amount of heat released by combusting a specified quantity (initially at 25°C) and returning the temperature of the combustion products to 150°C. This assumes the latent heat of vaporization of water in the reaction products is not recovered.

However, for the purpose of regulating the heating value in the context of the present disclosure, the actual heating value of the vapour fraction being discharged does not need to be determined on an absolute basis. Generally it is sufficient to regulate the heating value relative to an actual demand for heating power, with the aim to minimize any shortage and excess of heating power being delivered.

In the context of the present description, cooling duty reflects the rate at which heat is exchanged in the condenser, which can be expressed in units of power (e.g. Watt or MWatt). The cooling duty is related to the flow rate of the auxiliary refrigerant being subjected to the heat exchanging against the overhead vapour.

Preferably, the cooling duty is automatically adjusted in response to a signal that is causally related to the heating value being regulated. In embodiments wherein the vapour fraction is passed to one or more selective consumers of methane, such as for instance the combustion device 220 shown in Figure 1, the controlling can be done in response to the demanded heating power, whereby the partial flow rate of methane is controlled to achieve a heating value that matches the demand. Suitably, the auxiliary refrigerant stream flow control valve 135 may be controlled by the pressure controller PC to maintain a predetermined target flow rate of auxiliary refrigerant stream 132 through the overhead condenser 35. The actual pressure in the vapour fraction discharge line 80 is causally related to the heating value that is being regulated. The pressure controller PC will be set to decrease the open fraction of the auxiliary refrigerant stream flow control valve 135 when the pressure drops below a pre-determined target level, which is indicative of a higher consumption rate of methane than supply rate in the vapour fraction 80. Conversely, the pressure controller PC will be set to increase the open fraction of the auxiliary refrigerant stream flow control valve 135 when the pressure exceeds the pre-determined target level.

The vapour fraction 80 is envisaged to contain between from 50 mol% to 95 mol% of nitrogen, preferably between from 70 mol% to 95 mol% of nitrogen or between from 50 mol% to 90 mol% of nitrogen, more preferably between from 70 mol% to 90 mol% of nitrogen, still more preferably from 75 mol% to 95 mol% of nitrogen, most preferably from 75 mol% to 90 mol% of nitrogen. The condensed fraction 37 is contemplated to contain less than 35 mol% of nitrogen.

The auxiliary refrigerant 132 stream preferably has a bubble point under standard conditions at a lower temperature than the bubble point of the overhead vapour stream 30 under standard conditions (ISO 13443 standard: 15 °C under 1.0 atmosphere). This facilitates recondensing a relatively high amount of the methane that is present in the overhead vapour stream 30, which in turn facilitates the controllability of the methane content in the vapour fraction 80. For instance, the auxiliary refrigerant may contain between from 5 mol% to 75 mol% of nitrogen. In a preferred embodiment, the auxiliary refrigerant stream is formed by a slip stream of the main refrigerant stream, more preferably by a slip stream of the light refrigerant fraction. This latter case is illustrated in Figure 2 but may also be applied in the embodiment of Figure 1. Such a slip stream may conveniently be passed back into the main refrigerant circuit via the shell side 186 of the cryogenic heat exchanger 180, where it may still assist in withdrawing heat from the stream in the upper and/or lower tube bundles.

In one example, a contemplated composition of the auxiliary refrigerant contains between 25 mol% and 40 mol% of nitrogen; between 30 mol% and 60 mol% of methane and up to 30 mol% of C_2 (ethane and/or ethylene), whereby the auxiliary refrigerant contains at least 95% of these constituents and/or the total of nitrogen and methane is at least 65 mol%. A composition within these ranges is may be readily available from the main refrigerant circuit if a mixed refrigerant is employed for sub-cooling of the liquefied hydrocarbon stream.

It is also possible to employ a separate refrigeration cycle for the purpose of partially condensing the overhead vapour stream 30. However, employing a slip stream from the main refrigerant stream has as advantage that the amount of additional equipment to be installed is minimal. For instance, no additional auxiliary refrigerant compressor and auxiliary refrigerant condenser would be needed.

If the nitrogen stripper column 20 is equipped with the optional internal rectifying section 22 as described above, the overhead vapour stream 30 is preferably obtained from an overhead space of the nitrogen stripping column 20 above the rectifying section 22.

At least a reflux portion 36 of the condensed fraction is allowed onto the rectifying section 22 in the nitrogen stripper column 20, starting at a level above the rectifying section 22. From here the reflux portion can percolate downward through the rectifying section 22, in contact with vapours rising upward through the rectifying section 22. In the case of the embodiment of Figure 1, the condensed fraction may pass through into the nitrogen stripper column 20 via the reflux inlet system 25. The reflux portion is suitably obtained from the condensed fraction and charged into the nitrogen stripper column 20 via the optional reflux pump 38 (and/or it may flow under the influence of gravity) and the reflux portion line 36. In the case of the embodiment of Figure 2, the condensed fraction is separated inside the overhead space of the nitrogen stripper column 20 and therefore already available above the rectifying section 22.

The reflux portion may contain all of the condensed fraction, but optionally, the condensed fraction is split in the optionally provided condensed fraction splitter 39 into a liquid recycle portion which is charged via liquid recycle line 13 into, for instance, the first feed stream 10, and the reflux portion which is charged into the nitrogen stripper column 20 via reflux inlet system 25 and reflux portion line 36.

The capability of splitting the condensed fraction into the reflux portion 36 and the liquid recycle portion 13 is beneficial to divert any excess liquid of the condensed fraction around the rectifying section 22 as a liquid recycle, such as not to upset the operation of the rectifying section 22. In embodiments wherein the liquid recycle portion is recycled into the nitrogen stripper column 20, bypassing of the internal rectifying section 22 can be accomplished by feeding the liquid recycle portion into the nitrogen stripper column 22 at a point gravitationally below the rectifying section 22.

The partially condensing may also involve direct and/or indirect heat exchanging with other streams in other consecutively arranged overhead heat exchangers. For instance, the cold recovery heat exchanger 85 may be such an overhead heat exchanger whereby the partially condensing of the overhead stream further comprises indirect heat exchanging against the vapour fraction 80.

The optional vapour recycle line 87 may be selectively employed, suitably by selectively opening the vapour recycle control valve 88, to increase the amount of nitrogen that remains in the liquid hydrocarbon product stream 90. This may be done by drawing a vaporous recycle portion from the vapour fraction, depressurising the vaporous recycle portion to the flash pressure and subsequently injecting the vaporous recycle portion into the nitrogen-stripped liquid 40. The remaining part of the vapour fraction 80 that is not passed into the vapour recycle line 87 may form the fuel portion that may be conveyed to the combustion device 220.

In some embodiments, the target amount of nitrogen dissolved in the liquid hydrocarbon product stream 90 is between 0.5 and 1 mol%, preferably as close to 1.0 mol% as possible yet not exceeding 1.1 mol%. The vapour recycle flow control valve 88 regulates the amount of the vapour fraction stream 80 that is fed back into, for instance, the end flash separator 50 while bypassing the nitrogen stripper column 20. Herewith the amount of nitrogen in the liquid hydrocarbon product stream 90 can be influenced. To further assist in meeting the target nitrogen content, the vapour recycle flow control valve 88 may be controlled in response to a signal from a quality measurement instrument QMI that is optionally provided in the liquid hydrocarbon product line 90.

The proposed method and apparatus are specifically suitable for application in combination with a hydrocarbon liquefaction system, such as a natural gas liquefaction system, in order to remove nitrogen from the raw liquefied product. It has been found that even when the raw liquefied product - or the cryogenic hydrocarbon composition - contains a fairly high amount of from 1 mol% (or from about 1 mol%) up to 5 mol% (or up to about 5 mol%) of nitrogen, the resulting liquid hydrocarbon product can meet a nitrogen content within a specification of between from 0.5 to 1 mol% nitrogen. The remainder of the nitrogen is discharged as part of the vapour fraction in the off gas, together with a controlled amount of methane.

It is suggested that the presently proposed method and apparatus are most beneficial when the raw liquefied product, or the cryogenic hydrocarbon composition, contains from 1.5 mol%, preferably from 1.8 mol%, up to 5 mol% of nitrogen. Existing alternative approaches may also work adequately when the nitrogen content is below about 1.8 mol% and/or below about 1.5 mol%.

Static simulations have been performed on the embodiment shown in Figure 1, for both holding mode (Table 1) and loading mode (Table 2). The cryogenic hydrocarbon composition 8 was assumed to consist for more than 90 mol% of a mixture of nitrogen and methane (98.204 mol%). In the example, the amount of nitrogen (1.654 mol%) and methane (98.204 mol%) is more than 99.8 mol%, the balance of 0.142 mol% consisting of carbon dioxide (0.005 mol%). The carbon dioxide leaves the process via the nitrogen stripped liquid 40 and the liquid hydrocarbon product stream 90. The split ratio in the initial stream splitter 9 was about 75 % in both cases.

It can be seen that in both holding mode and loading mode, despite the large difference in amount of process vapour, the amount of methane in the discharged vapour fraction 80 could be kept at about 80 mol% and well within the range of between 10 mol% and 25 mol% while at the same time the nitrogen content in the liquid hydrocarbon product stream 90 was kept within the target of close to 1.0 mol% and not exceeding 1.1 mol%.

In holding mode, about 2.0 kg/s of boil-off gas consisting of about 17 mol% nitrogen and 83 mol% methane was added to the process via the boil-off gas supply line 230, while in loading mode this was about 4.4 kg/s.

In holding mode no vapour was guided through the vapour bypass line 76, while in the loading mode 30% of the compressed vapour 70 was guided through the vapour bypass line 76 in order to accommodate the additional vapour brought about by the additional inflow of boil-off gas. The liquid recycle 13 in the loading mode also went

Table 1: Holding mode; Reference numbers correspond to Figure 1.

Ref. number	1	8	10	11	13	30	36	40	60	64	70	71	76	80	87	90
Phase (V/L)	L	L	L	L	L	V	L	L	V	V	V	V	-	V	V	L
Flow rate (kg/s)	134	134	36.1	99	0.55	11.3	6.60	45.8	14.4	12.4	14.4	14.4	0.00	4.1	1.44	134
Temp. (°C)	-162	-163	-163	-163	-159	-143	-159	-137	-162	-164	-72	-72	-	-159	-159	-164
Pressure (bara)	55	6.4	6.4	6.4	6.4	6.2	6.2	6.3	1.00	1.05	6.8	6.3	-	5.8	5.8	1.05
Nitrogen (mol%)	1.66	1.66	1.91	1.66	20.1	37.7	20.1	1.77	18.0	18.3	18.0	18.0	-	80.0	80.0	0.86
Methane (mol%)	98.3	98.3	98.1	98.3	79.9	62.3	79.9	98.2	82.0	81.7	82.0	82.0	-	20.0	20.0	99.1

Table 2: loading mode; Reference numbers correspond to Figure 1.

Ref. number	1	8	10	11	13	30	36	40	60	64	70	71	76	80	87	90
Phase (V/L)	L	L	L	L	L	V	L	L	V	V	V	V	V	V	V	L
Flow rate (kg/s)	134	134	36.8	102	4.80	17.8	6.91	45.0	19.1	14.6	19.1	13.5	5.53	6.1	3.3	136
Temp. (°C)	-162	-163	-162	-162	-160	-115	-160	-138	-154	-164	-56	-57	-57	-160	-160	-164
Pressure (bara)	55	6.4	6.4	6.4	6.4	6.2	6.2	6.3	1.00	1.05	6.8	6.3	6.2	5.8	5.8	1.05
Nitrogen (mol%)	1.66	1.66	3.90	1.66	20.9	37.3	20.9	2.15	21.3	22.5	21.3	21.3	21.3	81.0	81.0	1.09
Methane (mol%)	98.3	98.3	96.1	98.3	79.1	62.7	79.1	97.9	78.7	77.5	78.7	78.7	78.7	19.0	19.0	98.9

up, from about 8% to about 41% of the condensed fraction in the condensed fraction discharge line 37. The additional flow of condensed fraction is a result of additional re-condensed methane.

The liquefaction system 100 in the calculation used a line up as shown in Figure 2 with a mixed refrigerant in the compressed refrigerant line 120 with a composition as listed in Table 3 in the column labelled "120".

Table 3: mixed refrigerant composition (in mol%)

	120	121; 131; 132	
		Holding	Loading
Nitrogen	21.5	33.1	33.5
Methane	33.3	40.9	40.8
Ethane	0.13	0.07	0.07
Ethylene	32.6	23.1	22.8
Propane	12.2	2.79	2.81
Butanes	0.25	0.02	0.02

In holding mode the pressure in the compressed refrigerant line 120 was 58 bara, in loading mode higher, 61 bara. The aggregated pressure drop in the lower and upper LMR tube bundles (183 and 184, respectively) of the cryogenic heat exchanger is 13 bar in both cases. The pressure drop imposed by the auxiliary refrigerant stream flow control valve 135 was 39 bar in the holding mode case and 42 bar in the loading mode operation so that the shell pressure in shell side 186 of the cryogenic heat exchanger 180 was the same for both the holding mode as the loading mode.

The relative flow rate of the auxiliary refrigerant stream 132 consisted of 11 % of the total LMR flow rate in LMR line 131. In loading mode this was 18 %. Also the actual flow rate was 1.6x higher than in the holding mode case, but the separation between HMR and LMR in MR separator 128 was made to favour HMR a little bit more in the loading mode operation than in the holding mode operation.

In the above example, the cryogenic hydrocarbon composition was assumed to contain no hydrocarbons heavier than methane (C_2+ hydrocarbons), such as could be the case if the cryogenic hydrocarbon composition is derived from non-conventional gas sources, such as coal bed methane, shale gas, or perhaps certain synthetic sources. However, the proposed methods and apparatus may also be applied where the cryogenic hydrocarbon composition would contain up to about 15 mol% of C_2+ hydrocarbons, including one or more selected from the group consisting of ethane, propane, i-butane, n-butane, and pentane. In essence these additional C_2+ hydrocarbons are not expected to change the functioning of the proposed methods and apparatus, as it is anticipated that none of such C_2+ hydrocarbons would be found in the overhead vapour 30 or the off gas in vapour fraction discharge line 80, like the carbon dioxide of the example.

The person skilled in the art will understand that the present invention can be carried out in many various ways without departing from the scope of the invention.

CLAIMS

1. Method of removing nitrogen from a cryogenic hydrocarbon composition comprising a nitrogen- and methane-containing liquid phase, the method comprising:

- providing a cryogenic hydrocarbon composition comprising a nitrogen- and methane-containing liquid phase;
- feeding a first nitrogen stripper feed stream, at a stripping pressure, into a nitrogen stripper column comprising at least one internal stripping section positioned within the nitrogen stripper column, said first nitrogen stripper feed stream comprising a first portion of the cryogenic hydrocarbon composition;
- drawing a nitrogen-stripped liquid from a sump space of the nitrogen stripper column below the stripping section;
- producing at least a liquid hydrocarbon product stream and a process vapour from the nitrogen-stripped liquid, comprising at least a step of depressurizing the nitrogen-stripped liquid to a flash pressure;
- compressing said process vapour to at least the stripping pressure, thereby obtaining a compressed vapour;
- selectively splitting the compressed vapour into a stripping portion and a non-stripping portion that does not comprise the stripping portion, which non-stripping portion comprises a bypass portion of said compressed vapour;
- passing a stripping vapour stream into the nitrogen stripper column at a level gravitationally below said stripping section, said stripping vapour stream comprising at least the stripping portion of said compressed vapour;
- passing an intermediate vapour through a condenser whereby indirectly heat exchanging of the intermediate

vapour against an auxiliary refrigerant stream and partially condensing the intermediate vapour, wherein said intermediate vapour comprises at least the non-stripping portion of said compressed vapour, and wherein said heat exchanging comprises passing heat from the intermediate vapour to the auxiliary refrigerant stream at a cooling duty, whereby an excess liquid is formed from the intermediate vapour and whereby at least said bypass portion from the compressed vapour remains in vapour phase;

- discharging a vapour fraction as off gas, comprising a discharge fraction of an overhead vapour obtained from an overhead space of the nitrogen stripper column and comprising at least the bypass portion; and
- returning at least part of a liquid recycle portion to the liquid hydrocarbon product stream, wherein the liquid recycle portion comprises at least part of the excess liquid;

wherein from said selectively splitting to the discharging of the bypass portion in the vapour fraction of the off gas the bypass portion bypasses the at least one internal stripping section.

2. The method according to claim 1, wherein said partially condensing of the intermediate vapour results in a partially condensed intermediate stream comprising a condensed fraction and said vapour fraction, wherein said vapour fraction comprises said bypass portion and wherein said condensed fraction comprises said excess liquid, the method further comprising:

- selectively injecting the non-stripping portion of said compressed vapour into the overhead vapour obtained from the overhead space of the nitrogen stripper column, thereby forming said intermediate vapour; and

- separating the condensed fraction from the vapour fraction at a separation pressure, prior to said discharging of the vapour fraction as off gas.

3. The method according to claim 1 or 2, wherein the vapour fraction in the off gas has a heating value, the method further comprising:

- adjusting the cooling duty to regulate the heating value of the vapour fraction being discharged.

4. The method according to claim 2 or 3, wherein the nitrogen stripper column further comprises at least one internal rectifying section arranged within said nitrogen stripper column gravitationally higher than said stripping section within said nitrogen stripper column, said method further comprising:

- allowing at least a reflux portion of a condensed fraction to enter the rectifying section in the nitrogen stripper column from a level above the rectifying section.

5. The method according to claim 4, further comprising:

- splitting the condensed fraction into said reflux portion and the liquid recycle portion, whereby the liquid recycle portion does not comprise said reflux portion; and wherein said returning of at least part of the liquid recycle portion to the liquid hydrocarbon product stream comprises:

- diverting the liquid recycle portion around the rectifying section.

6. The method according to any one of claims 1 to 5, wherein after said selective splitting the stripping

portion has the same composition and phase as the non-stripping portion.

7. The method according to any one of claims 1 to 6, wherein the stripping pressure is in a range of between 2 and 15 bar absolute and/or wherein the flash pressure is between from 1 and 2 bar absolute.

8. The method according to any one of claims 1 to 7, further comprising passing at least a fuel portion of the vapour fraction to a combustion device at a fuel gas pressure not higher than the stripping pressure.

9. The method according to any one of claims 1 to 8, wherein the process vapour comprises boil-off gas obtained by adding heat to the liquid hydrocarbon product stream whereby a part of liquid hydrocarbon product stream evaporates to form said boil-off gas.

10. The method according to any one of claims 1 to 9, wherein a flash vapour is generated during said depressurizing of said nitrogen-stripped liquid to said flash pressure, and wherein the process vapour comprises said flash vapour.

11. The method according to any one of claims 1 to 10, wherein said providing of said cryogenic hydrocarbon composition comprises:

- heat exchanging a feed stream containing a hydrocarbon containing feed vapour in a cryogenic heat exchanger against a main refrigerant stream, thereby liquefying the feed vapour of the feed stream to provide a raw liquefied stream; and
- obtaining the cryogenic hydrocarbon composition from the raw liquefied stream.

12. The method according to any one of claims 1 to 11, further comprising:

- drawing a vaporous recycle portion from the vapour fraction;
- depressurising said vaporous recycle portion to the flash pressure;
- injecting the vaporous recycle portion into at least one of the group consisting of: the nitrogen-stripped liquid, the liquid hydrocarbon product stream, and the process vapour.

13. The method according to any one of claims 1 to 12, wherein the auxiliary refrigerant stream contains between from 5 mol% to 75 mol% of nitrogen.

14. The method according to any one of claims 1 to 13, wherein the vapour fraction comprises between from 50 mol% to 95 mol% of nitrogen.

15. An apparatus for removing nitrogen from a cryogenic hydrocarbon composition comprising a nitrogen- and methane-containing liquid phase, the apparatus comprising:

- a cryogenic feed line connected to a source of a cryogenic hydrocarbon composition comprising nitrogen and a methane-containing liquid phase;
- a nitrogen stripper column in fluid communication with the cryogenic feed line, said nitrogen stripper column comprising at least one internal stripping section positioned within the nitrogen stripper column and a sump space defined gravitationally below the stripping section;
- a nitrogen-stripped liquid discharge line comprising an intermediate depressurizer, in fluid communication with the sump space of the nitrogen stripper column arranged to receive a nitrogen-stripped liquid from the sump space and

to depressurize the nitrogen-stripped liquid, said intermediate depressurizer located on an interface between a stripping pressure side comprising the nitrogen stripper column and a flash pressure side;

- a liquid hydrocarbon product line arranged on the flash pressure side in communication with the intermediate depressurizer, to discharge a liquid hydrocarbon product stream produced from the nitrogen-stripped liquid;
- a process vapour line arranged on the flash pressure side in communication with the intermediate depressurizer, to receive a process vapour produced from the nitrogen-stripped liquid;
- a process compressor arranged in the process vapour line arranged to receive the process vapour and compress the process vapour to provide a compressed vapour at a process compressor discharge outlet of the process compressor, said process compressor being on said interface between the stripping pressure side and the flash pressure side;
- a bypass splitter, whereby an upstream side thereof is in fluid communication with the discharge outlet of the process compressor to receive the compressed vapour, and of which bypass splitter a first discharge side is in fluid communication with the nitrogen stripper column via a stripping vapour line and a second inlet system arranged at a level gravitationally below the stripping section and arranged to receive at least a stripping portion of said compressed vapour from the process compressor, and of which bypass splitter a second discharge side is in fluid communication with a vapour bypass line containing a non-stripping portion of the compressed vapour;

- a condenser arranged in fluid communication with the vapour bypass line to bring an intermediate vapour that comprises at least the non-stripping portion from the vapour bypass line, which condenser comprises a heat exchanging surface providing indirect heat exchange contact between the intermediate vapour and an auxiliary refrigerant stream;
- a discharge line in communication with both the condenser and with an overhead space of the nitrogen stripper column, and arranged to discharge a vapour fraction as off gas comprising an overhead vapour obtained from the overhead space of the nitrogen stripper column and a bypass portion comprising a non-condensed vapour from the intermediate vapour that has passed through the condenser; and
- a liquid recycle line on its upstream side in fluid communication with the condenser and on its downstream side in liquid communication with the liquid hydrocarbon product line;

wherein a bypass path extends between the bypass splitter and the discharge line, wherein the bypass path bypasses the at least one internal stripping section and wherein the vapour bypass line extends along the bypass path.

16. The apparatus according to claim 15, wherein the condenser is arranged also in fluid communication with the overhead space of the nitrogen stripper column whereby said intermediate vapour comprises both the non-stripping portion from the vapour bypass line and the overhead vapour obtained from the overhead space of the nitrogen stripper column.

17. The apparatus according to claim 16, wherein the nitrogen stripper column further comprises at least one internal rectifying section arranged within said nitrogen stripper column gravitionally higher than said stripping section within said nitrogen stripper column, said apparatus further comprising a reflux system arranged to allow at least a reflux portion of a condensed fraction from the condenser to enter the rectifying section in the nitrogen stripper column from a level above the recitfying section, and a condensed fraction splitter arranged to receive the condensed fraction from the condenser, wherein the liquid recycle line is in fluid communication with the condenser via the condensed fraction splitter and in liquid communication with the liquid hydrocarbon product line via a recycle path that bypasses the rectifying section.

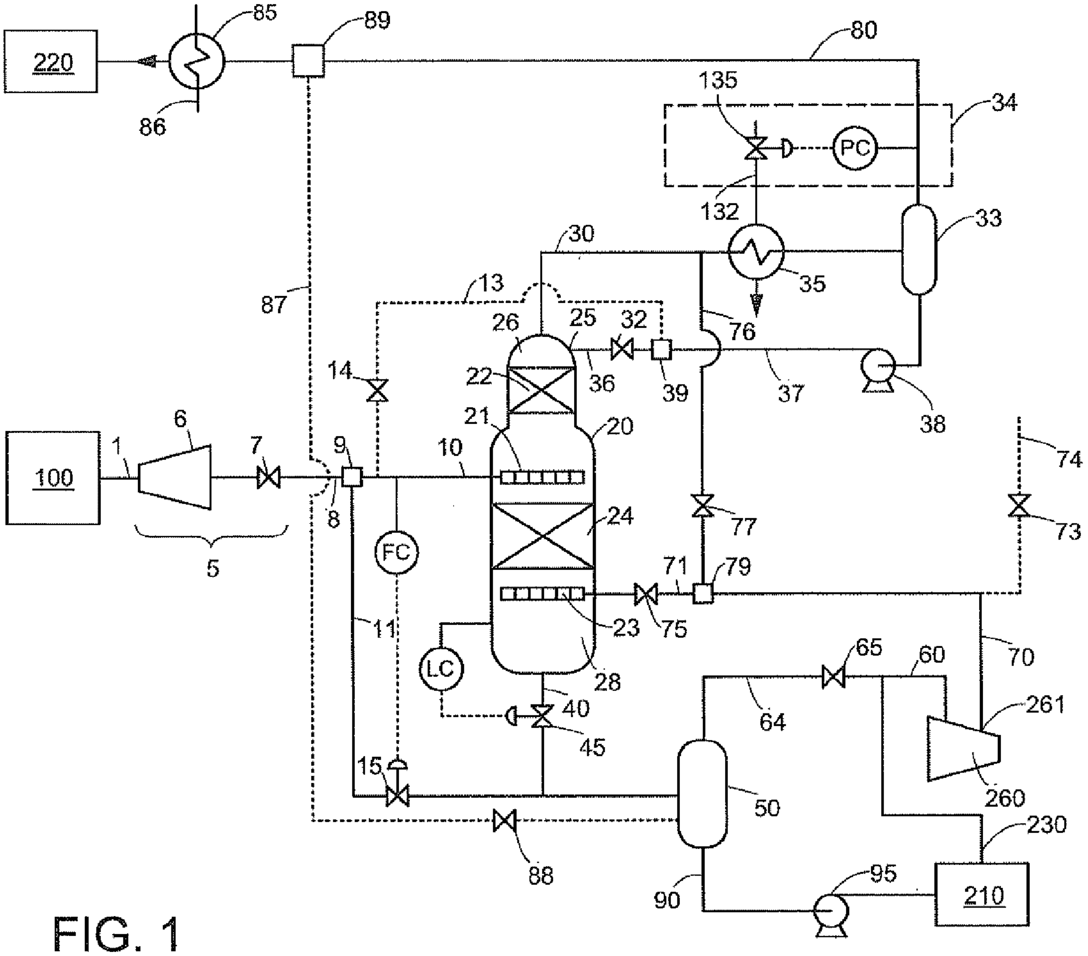
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FIG. 1

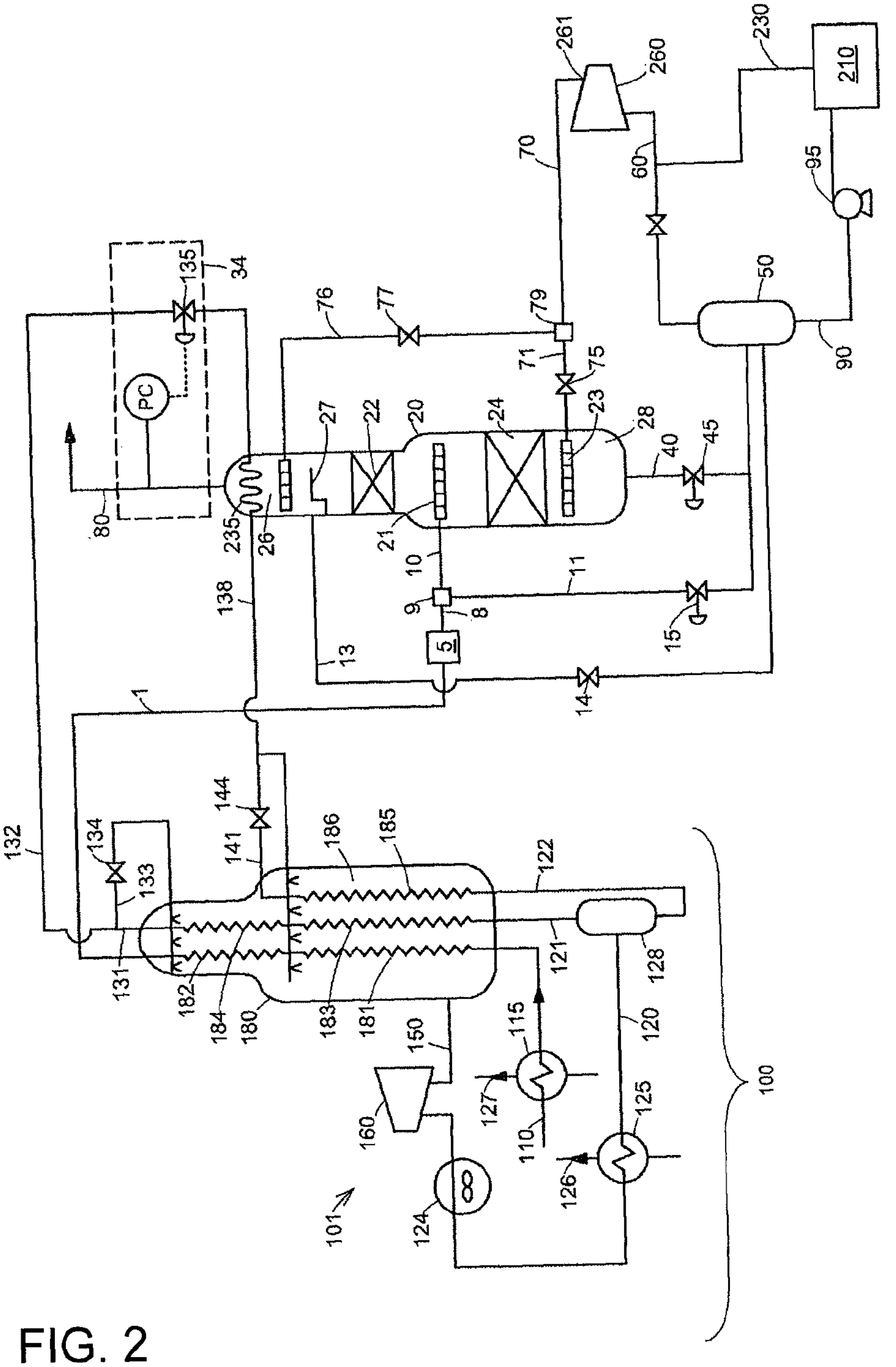
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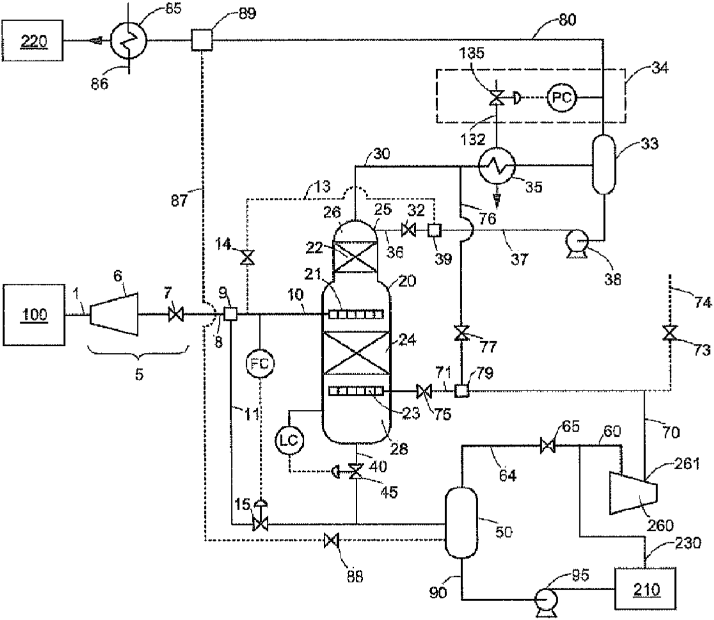
FIG. 2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