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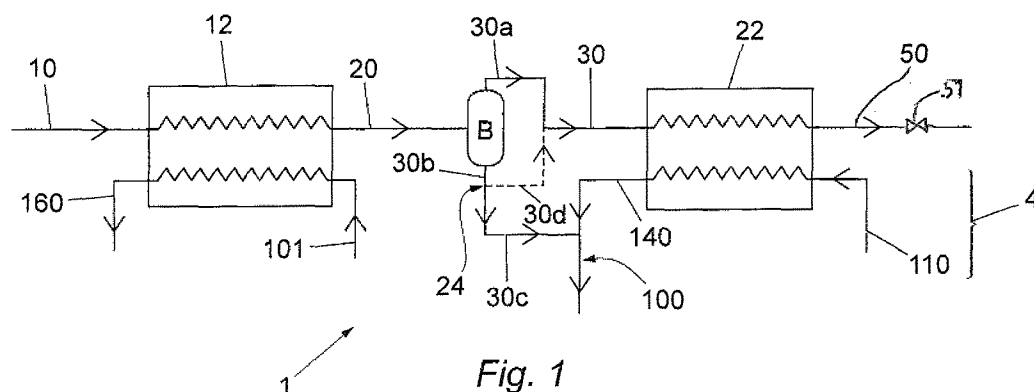


Fig. 1

(57) Abstract: A method of liquefying a hydrocarbon stream, such as natural gas, comprising at least the steps of : (a) partially liquefying a hydrocarbon feed stream (10) to provide a partially liquefied hydrocarbon stream (20); (b) passing the partially liquefied hydrocarbon stream (20) through a first gas/liquid separator (B) to provide a methane-enriched gaseous overhead stream (30a) and a mixed C_2^+ enriched liquid bottom stream (30b); (c) adding at least a part (30c) of the mixed C_2^+ enriched bottom stream (30b) to a mixed refrigerant circuit (4) to change the C_2^+ component inventory of the mixed refrigerant (100) in the mixed refrigerant circuit (4); and (d) liquefying the methane-enriched gaseous overhead stream (30a, 30) against at least a fraction (110, 125, 135) of the mixed refrigerant (100) in the mixed refrigerant circuit (4) to provide a liquefied hydrocarbon stream (50).

METHOD AND APPARATUS FOR LIQUEFYING A HYDROCARBON STREAM
AND FLOATING VESSEL OR OFFSHORE PLATFORM COMPRISING THE
SAME

The present invention relates to a method and apparatus for liquefying a hydrocarbon stream. In other aspects, the present invention relates to a floating vessel or an offshore platform comprising such an apparatus or on which such a method is performed.

A commonly suggested hydrocarbon feed stream may comprise or essentially consist of natural gas, but it could also be derived from other sources.

Several methods of liquefying a natural gas stream thereby obtaining liquefied natural gas (LNG) are known. It is desirable to liquefy 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 a high pressure.

US 3,274,787 describes a method wherein natural gas is liquefied. The natural gas, which contains methane, C₂ to C₄ and some C₅ and C₆ hydrocarbons, arrives through a conduit in a heat exchanger where it is cooled and slightly condensed and then passes to a separator. The remaining natural gas is further cooled, liquefied and sub-cooled. The condensate enriched in heavier hydrocarbons passes through an expansion valve to a rectification column, which is heated at the bottom. The residual liquid separated in the sump of the rectification column is introduced into a train of fractionation columns each equipped with a condenser and

a heater. Propanes and butanes drawn from the tops of the fractionation columns are combined with recycled fractions of cycling gas, which is used to cool the natural gas, in order to compensate for inevitable butane and propane losses in the recycling gas.

Thus, the process of US 3,274,787 requires a plurality of fractionation columns, in addition to a rectifier column. These are expensive to build and operate, and also occupy plot space.

US 7,234,321 describes another method for liquefying methane-rich gas. A stream of incoming feed gas (which has been treated to remove components that would interfere with the liquefaction, such as freezables) is pre-cooled and separated in a condensate separator into a vapour stream and a liquid condensate stream which consists mainly of propane, butane and C₅⁺. One of the purposes of this separation is to provide a source for refrigerant fluid. The condensate liquid stream is flashed, heated and fed into another separator to remove most of the methane content from the liquid. A portion of the liquid, after further heating, enters into yet another separator. The vapour stream from this separator is admitted, when required, to the inventory of refrigerant in a closed circuit refrigeration system. Liquid may be removed from the refrigeration system in order to change the composition of the refrigerant.

The cycled refrigerant in US 7,234,321 is used to cool the gas to a temperature of about -75 to -85 °C before it flows to a liquefying expander wherein the gas is liquefied.

The process of US 7,234,321 uses only separators, and no fractionation, to remove the natural gas liquids from the natural gas. It is therefore a drawback in this

process that is will be difficult to get rid of all the methane and other light components such as nitrogen in the natural gas liquid stream, and in particular in the vapour part of the natural gas liquid stream that is used to feed into the refrigerant inventory. These components do not condensate and are therefore not effective in removing heat from the natural gas. Moreover, these components are hard to separate from the other components in the refrigerant at the relative high temperatures (about -75 to -85 °C) at which the refrigerant cycle is operated.

The present invention provides a method of liquefying a hydrocarbon stream, comprising at least the steps of:

- (a) partially liquefying a hydrocarbon feed stream to provide a partially liquefied hydrocarbon stream;
- (b) passing the partially liquefied hydrocarbon stream through a first gas/liquid separator to provide a methane-enriched gaseous overhead stream and a mixed C_2^+ enriched liquid bottom stream;
- (c) circulating a mixed refrigerant through a mixed refrigerant circuit;
- (d) adding, without fractionation, at least a part of the mixed C_2^+ enriched bottom stream to the mixed refrigerant circuit to change the C_2^+ component inventory of the mixed refrigerant in the mixed refrigerant circuit; and
- (e) liquefying the methane-enriched gaseous overhead stream by heat exchanging against at least a fraction of the mixed refrigerant circulating in the mixed refrigerant circuit, to provide a liquefied hydrocarbon stream.

The present invention also provides an apparatus for liquefying a hydrocarbon stream, the apparatus at least comprising:

one or more first heat exchangers for partially
5 liquefying a hydrocarbon feed stream to provide a partially liquefied hydrocarbon stream;

a first gas/liquid separator (B) through which the partially liquefied hydrocarbon stream can pass to provide a methane-enriched gaseous overhead stream and a
10 mixed C_2^+ enriched liquid bottom stream;

a mixed refrigerant circuit comprising a mixed refrigerant;

one or more lines to pass at least a part of the mixed C_2^+ bottom stream into the mixed refrigerant
15 circuit, without a fractionator, to change the component inventory of mixed refrigerant; and

one or more second heat exchangers to liquefy the methane-enriched gaseous overhead stream using at least a fraction of the mixed refrigerant to provide a liquefied
20 hydrocarbon stream.

The present invention further provides a floating vessel and an off-shore platform, e.g. in the form of a caisson, having apparatus and/or using a method as defined herein.

25 Embodiments of the present invention will now be described by way of example only, and with reference to the accompanying non-limiting drawings in which:

Figure 1 is a diagrammatic scheme of a hydrocarbon liquefying process showing an embodiment of the present
30 invention;

Figure 2 is a more detailed scheme of Figure 1 showing various embodiments of the present invention; and

Figure 3 is a diagrammatic floating vessel showing another embodiment of the present invention.

For the purpose of this description, a single reference number will be assigned to a line as well as a stream carried in that line. Same reference numbers refer to similar components.

The present disclosure provides an improved method of liquefying a hydrocarbon stream, such as natural gas, which can be self-sufficient in changing its mixed refrigerant inventory, in particular in a space-limited location such as on a floating vessel.

Moreover, the present disclose provides an improved method of liquefying a hydrocarbon stream, such as natural gas, which does not require fractionation to change the mixed refrigerant inventory.

It is presently proposed to provide a refrigerant portion from a hydrocarbon feed stream by partially liquefying the hydrocarbon feed stream followed by simple separation and not fractionation of the partially liquefied hydrocarbon stream in a first gas/liquid separator to provide a mixed C_2^+ enriched stream. The mixed C_2^+ enriched stream can be used to change the C_2^+ component inventory of the mixed refrigerant in a mixed refrigerant circuit.

The term fractionation implies use of a fractionation column, which is understood to be any type of distillation column that has a source of heat in the lower part of the column (such as a warm stream (e.g. a reboiler stream) or a heating coil) and/or a drain of heat at the top (such as a condenser or a cold stream such as a reflux stream). Separation, as opposed to fractionation, merely separates vapour and liquid phases from a mixed phase stream, but does not involve such

source and/or drain of heat. As a result, separation is not very selective in terms of separating molecules, which thermodynamically inevitably causes a relatively high amount of light molecules such as methane and nitrogen to be present in the mixed C_2^+ enriched bottom stream which is used to change the mixed refrigerant inventory.

However, in the present invention this is not a problem because the mixed refrigerant is used to liquefy the methane-enriched vapour stream. In order to reach temperatures low enough to liquefy the methane-enriched vapour stream, a certain inventory of light molecules in the mixed refrigerant is effective.

Moreover, even if the concentration of light molecules in the mixed refrigerant happens to become too high, it is relatively easy to separate and remove these molecules from the mixed refrigerant because of the low temperatures needed anyway to liquefy the methane-enriched vapour stream.

In the present specification, the term "liquefy", as opposed to "partially liquefy", implies full liquefaction.

An advantage of the present invention is that a fractionation column is not required to further fractionate the C_2^+ enriched stream before using it to change the mixed refrigerant inventory. This saves space. It also saves the need for further processing units and equipment, including separate storage facilities, for providing every separate hydrocarbon which it usually desired to have available for changing the C_2^+ component inventory of a mixed refrigerant in a mixed refrigerant circuit. This is especially propane and butane storage

tanks, which require higher safety requirements, especially in space-limited environments.

The present invention may provide a source of one or more of the components of the mixed refrigerant from one or more of the gas/liquid separators described herein, so that change of the component inventory of the mixed refrigerant can be provided for from the method of liquefying without separate supply of one of the more of the components. Separate supply is conventionally provided in the art by the location of a number of storage tanks nearby to the hydrocarbon liquefying process, each storage tank storing one separated component such as ethane, propane, etc, which can supply its component to the mixed refrigerant on demand. It is an advantage of the present invention that separate nearby storage of the components of the mixed refrigerant can be avoided.

Each gas/liquid separator throughout the present disclosure may be provided in the form of a tank, optionally provided with internals as known in the art including a schoepentoeter and/or a mist mat and/or a swirl deck.

Figure 1 shows a general scheme 1 for a hydrocarbon liquefying process, generally involving cooling and liquefying a hydrocarbon feed stream 10, such as natural gas, by heat exchanging against a mixed refrigerant stream being circulated in a mixed refrigerant circuit 4.

The hydrocarbon feed stream 10 may be any suitable gas stream to be cooled and liquefied, but is usually a methane-comprising gas stream such as a natural gas stream obtained from natural gas or petroleum reservoirs. As an alternative the hydrocarbon feed stream may also be

obtained from another source, also including a synthetic source such as a Fischer-Tropsch process.

Usually a natural gas stream is comprised substantially of methane. Preferably the hydrocarbon feed stream comprises at least 50 mol% methane, more preferably at least 80 mol% methane.

Depending on the source, natural gas may contain varying amounts of hydrocarbons heavier than methane such as in particular ethane, propane and the butanes, and possibly lesser amounts of pentanes and aromatic hydrocarbons. The composition varies depending upon the type and location of the gas.

Conventionally, the hydrocarbons heavier than butanes are removed as far as efficiently possible from the hydrocarbon feed stream prior to any significant cooling for several reasons, such as having different freezing (particularly those higher than liquefaction temperature of methane) temperatures that may cause them to block parts of a methane liquefaction plant. Ethanes, propanes, and butanes are typically removed to meet a desired specification of the liquefied hydrocarbon product such as LNG.

It is presently intended that the hydrocarbon feed stream is maintained with at least some of the hydrocarbons heavier than methane. At least some of the hydrocarbons heavier than methane may still be removed if desired, for example where relatively few heavier hydrocarbons are expected to be required as described hereinafter. Preferably, there is less or even no heavy hydrocarbon removal from the hydrocarbon feed stream during start-up of the liquefaction process, so that there are more heavier hydrocarbons available for addition to the mixed refrigerant circuit.

Another advantage of the present invention is that it is not limited to only refilling the refrigerant with a single component fraction, such as an ethane-rich fraction as is the case in US 5,588,306.

5 The hydrocarbon feed stream may also contain non-hydrocarbons such as H₂O, N₂, CO₂, Hg, H₂S and other sulphur compounds, and the like. If desired, the hydrocarbon feed stream comprising the natural gas may be pre-treated before cooling and liquefying to remove such
10 components. This pre-treatment may comprise reduction and/or removal of undesired components such as CO₂ and H₂S or other steps such as early cooling, pre-pressurizing or the like. As these steps are well known to the person skilled in the art, their mechanisms are
15 not further discussed here.

To provide a partially liquefied hydrocarbon stream, the hydrocarbon feed stream 10 as hereinbefore described could be cooled prior to feeding it into a first gas/liquid separator (B). Such initial cooling could be
20 provided by a number of methods known in the art. One example is by passing the hydrocarbon feed stream 10 against a refrigerant (101,160), such as at least a first fraction of the mixed refrigerant of the mixed refrigerant circuit, in one or more first heat exchangers
25 12, to provide a partially liquefied hydrocarbon stream 20. The partially liquefied hydrocarbon stream 20 is preferably at a temperature below 0°C.

Preferably, any such first heat exchangers 12 producing a partially liquefied hydrocarbon stream could
30 form part of a first cooling stage, and one or more second heat exchangers 22 used to liquefy any part of the hydrocarbon stream could form part of one or more second or third cooling stages.

In this way, the present invention may involve two or more cooling stages, each stage having one or more steps, parts etc. For example, each cooling stage may comprise one to five heat exchangers. The or a part of a hydrocarbon stream and/or the mixed refrigerant may not pass through all, and/or all the same, the heat exchangers of a cooling stage.

In one embodiment of the present invention, the hydrocarbon liquefying process comprises two or three cooling stages. A first cooling stage is preferably intended to reduce the temperature of a hydrocarbon feed stream to below 0°C, usually in the range -20°C to -70°C. Such a first cooling stage is sometimes also termed a 'pre-cooling' stage.

The second cooling stage is preferably separate from the first cooling stage. That is, the second cooling stage comprises one or more separate heat exchangers 22. Such a second cooling stage is sometimes also termed a 'main cooling' stage.

The second cooling stage is preferably intended to reduce the temperature of a hydrocarbon stream 30, usually at least a part (30a) of the partially liquefied hydrocarbon stream 20 cooled and partially liquefied by the first cooling stage, to below -100°C.

Heat exchangers for use as the one or more first or the one or more second heat exchangers are well known in the art. At least one of the second heat exchangers is preferably a spool-wound cryogenic heat exchanger known in the art. Optionally, a heat exchanger could comprise one or more cooling sections within its shell, and each cooling section could be considered as a cooling stage or as a separate 'heat exchanger' to the other cooling locations.

Further, the person skilled in the art will readily understand that after liquefaction, the liquefied hydrocarbon stream 50 may be further processed, if desired. As an example, the obtained LNG may be
5 depressurized by means of a Joule-Thomson valve 51 and/or by means of a cryogenic turbo-expander.

In yet another embodiment of the present invention, the method further comprises the steps of:

(f) passing one or more fractions of the mixed
10 refrigerant through one or more heat exchangers to provide one or more cooled mixed refrigerant streams;

(g) passing at least one of the cooled mixed refrigerant streams through one or more refrigerant gas/liquid separators to provide one or more gaseous overhead
15 refrigerant streams and one or more liquid bottom refrigerant streams; and

(h) removing at least a part of at least one of the gaseous overhead refrigerant streams and the liquid bottom refrigerant streams to change the component
20 inventory of the mixed refrigerant circuit.

The mixed refrigerant of the mixed refrigerant circuit may be formed from a mixture of two or more components selected from the group comprising: nitrogen, methane, ethane, ethylene, propane, propylene, butanes,
25 pentanes, etc. The present invention may involve the use of one or more other refrigerants, in separate or overlapping refrigerant circuits or other cooling circuits.

A mixed refrigerant or a mixed refrigerant stream as
30 referred to herein comprises at least 5 mol% of two different components. A common composition for a mixed refrigerant can be:

- 12 -

	Nitrogen	0-10 mol%
	Methane (C ₁)	30-70 mol%
	Ethane (C ₂)	30-70 mol%
	Propane (C ₃)	0-30 mol%
5	Butanes (C ₄)	0-15 mol%

The total composition comprises 100 mol%.

It is known that the composition and inventory of a mixed refrigerant may be varied by a liquefaction plant user depending upon the geographical location of the liquefaction plant, one factor being the expected daily or weekly average ambient temperature, and another factor being seasonal adjustment to take account of variation in ambient temperature over a year. A refrigerant stream may also need replenishment due to leakage.

The present invention may also provide a process for reducing one or more of, optionally each of, the above components from a mixed refrigerant circuit via one or more of the gas/liquid separators and/or one or more of the heat exchangers involved, so that change of the component inventory of the mixed refrigerant in the mixed refrigerant circuit can also be provided thereby. Removal of a component also changes the composition and/or inventory of the mixed refrigerant. In its simplest form, one or more fractions of the mixed refrigerant can be removed from the mixed refrigerant circuit to change the component inventory of the mixed refrigerant.

For example, a fraction of the mixed refrigerant in a heat exchanger, such as the first 12 and second heat exchanger(s) 22, is at least partly evaporated in cooling and/or liquefying the hydrocarbon stream, to provide a bottom refrigerant stream (respectively 180a 180b) and a gaseous refrigerant overhead stream (respectively 190a

190b) from the heat exchanger (respectively 12, 22a), and at least a part of at least one of the gaseous refrigerant overhead stream and/or bottom refrigerant stream could also be removed from the mixed refrigerant to change the component inventory of the remaining mixed refrigerant.

The term "inventory" as used herein relates to both the amount (in mass or volume) of all the components, and to the percentage or proportion (as a ratio or %) of each component, in the mixed refrigerant circuit. Thus, the addition of a stream may change the amount of all the components, but not necessarily the proportions of the components, in a mixed refrigerant circuit. Addition of a stream having one or more specific components, or at least a majority of such component(s), can change both the amount and the proportions of the component(s) of the mixed refrigerant circuit. Similarly, removal of a phase of a stream from a separator through which at least a part of the mixed refrigerant passes, may change both the total amount of components of the mixed refrigerant circuit, and change the component proportions, as usually a separator provides a component(s)-specific stream.

In this way, the present invention can also provide a combination of a method of increasing and a method of reducing the inventory of one or more mixed refrigerant components in a mixed refrigerant circuit from only the mixed refrigerant circuit and/or a hydrocarbon stream being liquefied thereby.

The mixed refrigerant may initially be formed of a hydrocarbon feed stream. During start-up of the method of liquefying, the mixed refrigerant may for instance initially be a natural gas stream from which only the C_5^+ components have been removed. Then, as the method of

liquefying proceeds through its start-up procedure, the component inventory of the mixed refrigerant can be changed using the method of the present invention, to achieve an inventory of the mixed refrigerant as desired, such as that described hereinbefore. In this way, the present invention provides a self-sufficient method of changing the mixed-refrigerant to that desired, even from a start-up procedure.

The present invention may provide a nominal capacity (or name plate) of a liquefied hydrocarbon stream in the range of 1 to 8 millions (metric) tonnes per annum (MTPA). The term "nominal capacity" is defined at the daily production capacity of a plant multiplied by the number of days per years the plant is intended to be in operation. For instance, some LNG plants are intended to be operational for an average of 345 days per year. Preferably the nominal capacity of the hydrocarbon cooling process of the present invention is in the range of 2 to 3 MTPA.

Referring to the drawings, Figure 1 shows a general scheme 1 for a hydrocarbon liquefying process. As part of a hydrocarbon liquefying process, and prior to any major cooling, an initial hydrocarbon stream containing natural gas is conventionally pre-treated to reduce and/or remove heavier hydrocarbons therefrom. A common form of such separation is termed 'natural gas liquids' (NGL) extraction, in which proportions of C_2^+ hydrocarbons are removed from the gas stream - to provide a methane-enriched stream which is subsequently cooled - and fractionated to provide one or more single or multi-component streams for the C_2^+ components, such as NGL and LPG product streams.

In the present invention, at least some removal of heavier hydrocarbons may still be desired where less C_2^+ components are subsequently required to change the component inventory of the mixed refrigerant. However, it is a further benefit of the present invention that less or no prior separation of heavier hydrocarbons is required from the initial hydrocarbon stream as discussed hereinafter. The initial hydrocarbon stream may nevertheless have initially been cleared from C_5^+ components prior to its use. Such C_5^+ removal can be carried out using a separator such as a scrub column or an NGL extraction column, of significantly reduced size and scale compared to columns required for C_2^+ separation and fractionation, such that there is further CAPEX, OPEX and beneficial space-saving in this way.

In a hydrocarbon liquefying start-up procedure, it is possible for the initial hydrocarbon stream to be initially used as a or the refrigerant stream, whose component inventory can then be changed in a manner as discussed hereinafter. In this way, separate provision and/or storage of each of the mixed refrigerant components in advance of the start-up is not required, leading to further space saving.

After any pre-treatment and C_5^+ -removal, processes, steps or stages, optionally carried out remotely such as described in for instance WO 2008/006788, the initial hydrocarbon stream is provided as a hydrocarbon feed stream 10 as shown in Figure 1.

The hydrocarbon feed stream 10 passes through one or more heat exchangers 12 which can also define a first cooling stage. Preferably, the first cooling stage cools the hydrocarbon feed stream 10 to below 0°C , such as

between -20°C and -70°C, preferably either between -20°C and -45°C, or between -40°C and -70°C, to provide a partially liquefied hydrocarbon stream 20. Cooling in the one or more first heat exchangers 12 can be provided by an incoming first refrigerant stream 101, which is at least partially evaporated and discharged from the heat exchanger(s) 12 as an outgoing first refrigerant stream 160 in a manner known in the art.

The partially liquefied hydrocarbon stream 20 then passes into a first gas/liquid separator "B" to provide a methane-enriched gaseous overhead stream 30a and a mixed C₂⁺ enriched liquid bottom stream 30b. In its simplest form, the first gas/liquid separator B may consist of a pressure vessel, whose use and installation minimises CAPEX and OPEX for the process, because no fractionation of the partially liquefied hydrocarbon stream 20 is required to provide the mixed C₂⁺ enriched liquid bottom stream 30b.

The mixed C₂⁺ enriched liquid bottom stream 30b comprises at least 5 mol% of two different C₂⁺ components, such as ethane, propane and butane.

The C₂⁺ enriched liquid bottom stream 30b can be divided by a divider 24 into a separated portion 30c, useable to change the C₂⁺ component inventory of the mixed refrigerant 100 in a mixed refrigerant circuit 4 as hereinafter described, and a continuing stream 30d. The division of the C₂⁺ enriched liquid bottom stream 30b may be between 0-100%, depending upon various factors including the amount of the part stream 30c required to change the component inventory of the mixed refrigerant 100. In some circumstances, such as during start-up, a

high percentage, including but not limited to 100%, of the C_2^+ enriched liquid bottom stream 30b may be required to change the C_2^+ component inventory of the mixed refrigerant 100. Under other circumstances, such as
5 during a settled and continuing cooling period, little or 0% of the C_2^+ enriched liquid bottom stream 30b may be required for the part stream 30c.

The methane-enriched gaseous overhead stream 30a and that proportion of the C_2^+ enriched liquid bottom stream
10 30b provided as the continuing stream 30d can be combined to provide a combined cooled hydrocarbon stream 30 for subsequent processing as described hereinafter.

The component inventory of the part stream 30c will vary depending upon the nature of the hydrocarbon feed
15 stream 10, the degree of cooling provided by the one or more first heat exchangers 12, and/or the pressure and/or temperature of the first gas/liquid separator B. Typically, the heavier hydrocarbon proportions of the part stream 30c will be greater than the proportions of
20 the same components of the partially liquefied hydrocarbon stream 20 prior to separation in the first gas/liquid separator B.

The part stream 30c can be added into the mixed refrigerant 100 at any suitable location around the mixed
25 refrigerant circuit 4, and where its component proportions are different to that of the mixed refrigerant 100 at that point of the mixed refrigerant circuit 4, then the component proportions of the mixed refrigerant thereafter in the mixed refrigerant circuit 4
30 will change. Typically, the part stream 30c provides a source of one or more of ethane, propane and one or more of the butanes.

Where the pressure of the part stream 30c is different to that of the mixed refrigerant 100 at the intended point of their combination, one or more pressure-reducing valves may be used. By way of example only, the part stream 30c could be at a pressure above 50 bar, whilst the mixed refrigerant 100 may be in the range 1-10 bar. Pressure-reducing valves can include "knock-out" drums known in the art, which drums are also able to take off a usually heavier hydrocarbon liquid stream. In normal operations, it is not intended to alter the component proportions of the portion stream 30c prior to its addition to the mixed refrigerant 100.

The combined cooled hydrocarbon stream 30 in Figure 1 passes to one or more second heat exchangers 22, preferably a main cryogenic heat exchanger. After passage through the second heat exchanger 22, there is provided a liquefied hydrocarbon stream 50.

Cooling in the one or more second heat exchangers 22 is provided by an incoming second refrigerant stream 110 comprising at least a fraction of the mixed refrigerant of the mixed refrigerant circuit 4. The second refrigerant stream 110 is at least partly evaporated through the one or more second heat exchangers 22 to provide an outgoing second refrigerant stream 140 in a manner known in the art.

In various embodiments of the present invention, the method of liquefying a hydrocarbon stream comprises one refrigerant circuit comprising one mixed refrigerant, preferably being evaporated at different temperature and pressure levels. The inventory of the mixed refrigerant may change around the circuit according to additions or removals of stream parts as herein described as part of

the present invention. An example of such a so-called "single mixed refrigerant" process is shown in Figure 2.

Figure 2 is a more detailed scheme 2 of a hydrocarbon liquefying process incorporating an embodiment of the general scheme 1 shown in Figure 1. As with Figure 1, there is provided a hydrocarbon feed stream 10 which may have been pre-treated to reduce and/or remove at least some of the non-hydrocarbons in an initial feed stream such as natural gas, and optionally some of the hydrocarbons heavier than methane, particularly those heavier than butane, as discussed hereinabove.

The hydrocarbon feed stream 10 passes through a first heat exchanger 12, which may comprise one or heat exchangers in series, parallel, or both, in a manner known in the art.

The cooling in the first heat exchanger 12 is provided by a first fraction 154 of the mixed refrigerant 100. In the scheme 2 shown in Figure 2, the first fraction 154 is shown passing into the top or upper part of the first heat exchanger 12. The provision of the first fraction 154 is described herein below. After providing its cooling in the first heat exchanger 12, the first fraction 154 becomes an at least partly evaporated, usually fully evaporated, mixed refrigerant stream 160.

The cooled hydrocarbon stream 20 then passes into the first gas/liquid separator B to provide a methane-enriched gaseous overhead stream 30a and a mixed C_2^+ enriched liquid bottom stream 30b. The C_2^+ enriched liquid bottom stream 30b can be divided by a divider 24 into a separated part 30c, useable to change the C_2^+ component inventory of the mixed refrigerant 100 as hereinbefore described, and a continuing stream 30d which

can be combined with the methane-enriched gaseous overhead stream 30a to provide a combined cooled hydrocarbon stream 30 for subsequent liquefying.

The part stream 30c can be added into the mixed refrigerant 100 at any suitable location around the mixed refrigerant circuit 4. Typically, the part stream 30c provides a source of one or more of ethane, propane and one or more of the butanes.

The second heat exchanger 22 has two sections, a first or lower section, and a second or upper section. These are shown in Figure 2 as a first second heat exchanger 22a and a second second heat exchanger 22b. The arrangement of two or more heat exchangers as sections in a, for example cryogenic, heat exchanger are known in the art, and are not further discussed herein.

In another embodiment of the present invention, a second partly-liquefied hydrocarbon stream 40 formed after further cooling of the methane-enriched gaseous overhead stream in the one or more of the second heat exchangers 22, could be passed through a second gas/liquid separator (F) to provide a second methane-enriched - and optionally nitrogen-enriched - gaseous overhead stream 40a, and a second liquid bottom stream 40b. At least a part (40c) of the second liquid bottom stream 40b, could be used to change the component inventory of the mixed refrigerant circuit 4. The overhead and bottom streams from such a second gas/liquid separator F could provide different sources of one or more of the components required in the mixed refrigerant circuit 4.

Optionally, after some cooling of the combined cooled hydrocarbon stream 30, a further partially-liquefied hydrocarbon stream 40 outflows the second heat

exchanger 22 employing a bundle break below the top of the first section, and passes into a second gas/liquid separator F to provide a second methane-enriched, and optionally nitrogen-enriched, gaseous overhead stream 40a, and a second liquid bottom stream 40b. The temperature of the further partly liquefied hydrocarbon stream 40 may be such that little or no gaseous overhead stream 40a is produced.

The second liquid bottom stream 40b from the second gas/liquid separator F can optionally be divided (in a similar manner described hereinabove in relation to the liquid bottom stream 30b from the first gas/liquid separator B) into a second continuing stream 40d and a second separated stream 40c. The second continuing stream 40d can return as a return stream into the second heat exchanger 22 for further cooling in the second heat exchanger 22b, whilst the second separated stream 40c can be used to change the component inventory of the mixed refrigerant 100.

The component proportions of the second separated stream 40c will again vary depending upon a number of factors, but will usually predominantly be methane. Typically, the component proportions of the second separated stream 40c are different to the component proportions of the mixed refrigerant 100, such that the addition of the second separated stream 40c to the mixed refrigerant 100 will change the overall component proportions of the subsequent mixed refrigerant 100.

After passage through the second heat exchangers 22a, 22b, there is provided a liquefied hydrocarbon stream 50.

As in Figure 1, the obtained liquefied hydrocarbon stream 50 may be depressurized, e.g. by means of a Joule-Thomson valve 51.

The liquefied hydrocarbon stream may further be
5 passed through an end gas/liquid separator J such as an end-flash vessel to provide a gaseous overhead stream 60 and a liquid bottom stream 70, optionally for storage in a storage tank as the liquefied product such as LNG.

Where a part, preferably the coldest part, of the
10 refrigerant stream passes through a suitable gas/liquid separator, at least a part of the gaseous overhead stream from this gas/liquid separator could be combined with the gaseous overhead stream from the end gas/liquid separator, and optionally boil-off gas from the storage
15 tank, to provide a combined stream for compression and use as fuel gas.

Cooling of the combined cooled hydrocarbon stream 30 in the second heat exchangers 22a, 22b is provided by two fractions 125, 135 of the mixed refrigerant 100, which
20 fractions enter the second heat exchanger 22 at different locations, so as to provide the different heat-exchanging sections within the second heat exchanger 22 in a manner known in the art. At or near the base of the first second heat exchanger 22a, the mixed refrigerant after its use
25 can be collected as an at least partly, usually fully, evaporated mixed refrigerant stream 140, which passes through a refrigerant gas/liquid separator H to provide a compressor feed stream 141.

The refrigerant gas/liquid separator H may be a
30 knock-out drum. Any liquid bottom refrigerant stream 143 provided by the refrigerant gas/liquid separator H could also be removed from the mixed refrigerant 100 so as to

change the component proportions of the mixed refrigerant 100.

Line 140 also shows an example of one location where an additive stream such as stream 30c can be added to the mixed refrigerant circuit 4 comprising the mixed refrigerant 100 through line 200.

For example, an at least partly evaporated mixed refrigerant stream 160 from a first heat exchanger(s) 12 could pass through a second refrigerant gas/liquid separator (I) to provide a gaseous refrigerant stream 161 and a liquid bottom refrigerant stream 162. By removing at least a part of the liquid bottom refrigerant stream 162 from the mixed refrigerant stream 160 the component inventory of the remaining mixed refrigerant 100 in the mixed refrigerant circuit 4 could be changed.

The compressor feed stream 141 is compressed by a first compressor 32 to provide a first compressed stream 142, cooled by a first cooler 26, and then combined with the gaseous stream 161 from the refrigerant gas/liquid separator I to provide a combined compressor feed stream 170 for a second compressor 34. The second compressor 34 provides a compressed refrigerant stream 171, which passes through a second cooler 28 to provide a mixed refrigerant stream 101 ready for reuse. Line 202 shows a second example of a suitable location in the mixed refrigerant circuit 4 where an additive stream 202 can be added to the mixed refrigerant 100.

The second compressor 34 may optionally be provided with an intercooler 27 between successive stages. If such intercooler 27 is provided, an intercooler refrigerant gas/liquid separator K may be provided to clear any condensed fraction 203 of the refrigerant before supplying the remaining vaporous refrigerant to the next

compression stage in the second compressor 34. The liquid bottom refrigerant stream in line 203, or part thereof, may be pumped to higher pressure using one or more liquid pumps, and then reinserted into the refrigerant circuit in line 171, preferably downstream of second cooler 28.

The mixed refrigerant stream 101 can pass through a first refrigerant gas/liquid separator E to provide a gaseous overhead refrigerant stream 102 and a liquid bottom refrigerant stream 103.

The gaseous overhead refrigerant stream 102 and liquid bottom refrigerant stream 103 pass through the first heat exchanger 12. Where there are more than two first heat exchangers 12, such as 3, 4 or 5 heat exchangers, one or more of the hydrocarbon stream 10, the gaseous overhead refrigerant stream 102 and the liquid bottom refrigerant stream 103, may not pass through all of the first heat exchangers 12, but may be selected to pass through certain of the first heat exchangers 12 to provide a particular arrangement of cooling to the three streams in a manner known in the art.

The liquid bottom refrigerant stream 103 is cooled by its passage through the first heat exchanger 12 to provide a cooled stream 150, which can be expanded through a valve and passed into another refrigerant gas/liquid separator G, which provides a gaseous overhead refrigerant stream 151 and a liquid bottom refrigerant stream 152. The gaseous overhead refrigerant stream 151 can be divided in a manner similar to that described hereinabove for the liquid bottom stream 30b, to provide a fraction refrigerant stream 153 and a continuing refrigerant stream 153a, which continuing refrigerant stream 153a passes back into the first heat exchanger 12 as stream 154 to provide cooling as described

hereinabove. The fraction refrigerant stream 153 will typically be methane-enriched and usually also ethane-enriched, and provides another source of components which could be added to or removed from the mixed refrigerant 100. Its removal will typically increase the proportion of the heavier hydrocarbons in the mixed refrigerant 100. Its addition to the mixed refrigerant 100 may be at a time when a higher proportion of lighter hydrocarbons are required at another part of the mixed refrigerant circuit 4.

Similarly, the removal of at least a part 152a of the liquid bottom refrigerant stream 152, which typically has a greater proportion of heavier hydrocarbons than the gaseous overhead refrigerant stream 151, increases the proportion of lighter hydrocarbons in the mixed refrigerant 100. Alternatively, it may be used as a source of heavier hydrocarbons at another time or in another part of the mixed refrigerant circuit 4. The remaining part of the liquid bottom refrigerant stream 152 can be combined with the continuing part 153a of the gaseous overhead refrigerant stream 153 for passing back as stream 154 into the first heat exchanger 12 as the cooling medium therein.

The gaseous overhead refrigerant stream 102 from the refrigerant gas/liquid separator E is also cooled by the first heat exchanger 12 to provide a cooled refrigerant stream 110, which then passes through another refrigerant gas/liquid separator D to provide a gaseous overhead refrigerant stream 111 and a liquid bottom refrigerant stream 112. Typically, the liquid bottom refrigerant stream 112 has a greater proportion of heavier hydrocarbons, and is also typically termed a heavy mixed refrigerant stream (HMR). By means of a suitable divider

25, the liquid bottom refrigerant stream 112 can be arranged to provide between 0-100% of one, two or three further streams, these being a first cooling stage return stream 114 (to pass to the refrigerant gas/liquid separator G), a second cooling stage cooling stream 113 for use in the first second heat exchanger 22a, and a part stream 115 for removal from the mixed refrigerant circuit 4. Similar to separated refrigerant streams 152 and 162, the removal of part stream 115 changes the component inventory of the mixed refrigerant 100, (and the subsequent re-introduction of this part stream 115 into the mixed refrigerant circuit 4 at another location and/or time would also change the component inventory of the mixed refrigerant 100 at that location and/or time).

The gaseous overhead refrigerant stream 111 from the refrigerant gas/liquid separator D, commonly also termed a light mixed refrigerant stream (LMR), passes through the second heat exchanger 22 to provide a cooled refrigerant stream 120, which passes through a valve and into another refrigerant gas/liquid separator A. From the separator A, there is a gaseous overhead refrigerant stream 121 and a liquid bottom refrigerant stream 122.

Typically, the cooled refrigerant stream 120 is the coldest refrigerant stream in the refrigerant circuit 4, such that the gaseous overhead refrigerant stream 121 is typically enriched with nitrogen. Thus, separation of a part stream 123 from the gaseous overhead refrigerant stream 121 provides a source of a nitrogen-enriched stream and/or a source for removal of nitrogen from the mixed refrigerant 100. The remaining part stream 124 of the gaseous overhead refrigerant stream 121 can be combined with the liquid bottom refrigerant stream 122 to provide a fraction 125 of the mixed refrigerant 100 for

cooling in the second second heat exchanger 22b in a manner known in the art.

Similarly, the cooling stream 113, being at least a part of the liquid bottom refrigerant stream 112 from the refrigerant gas/liquid separator D, is also cooled by passage through the first second heat exchanger 22a to provide a cooled refrigerant stream 130, which is expanded by passage through a valve and passed into another refrigerant gas/liquid separator C, which provides a gaseous overhead refrigerant stream 131 and a liquid bottom refrigerant stream 132. A separated fraction 133 of the gaseous overhead refrigerant stream 131 is methane-enriched, and can also be nitrogen-enriched, whose removal from the mixed refrigerant circuit 4 changes the inventory of the mixed refrigerant 100. The remaining fraction 134 of the gaseous overhead refrigerant stream 131 can be combined with the liquid bottom refrigerant stream 132 to provide a fraction 135 for re-entry into the first second heat exchanger 22a and cooling in a common or separate section of the second heat exchanger 22 in a manner known in the art.

From the above, it can be seen that it is an advantage of the present invention to use one or more of a number of possible overhead streams and bottom streams. In this way, there can be greater flexibility of the composition proportions and/or inventory of the mixed refrigerant 100, especially all the different components of a mixed refrigerant 100, at any suitable location around the mixed refrigerant stream 4.

It is a further advantage of the present invention that by using one or more of a number of possible overhead streams and bottom streams from one or more of the hydrocarbon streams and the mixed refrigerant streams

at points around the cooling process or mixed refrigerant circuit, separate storage of the components of the mixed refrigerant can be avoided, such that there is some space saving that allows a process or a plant using the present invention to be arranged or designed with more space-efficiency, or otherwise to locate a process or plant using the present invention in a space-limited location not previously possible, such as on a floating vessel.

The scheme 2 shows use of a single mixed refrigerant circuit 4, although the present invention is not limited thereto. The use of single mixed refrigerant circuits to provide cooling to two or more different sets of heat exchangers is known in the art, and an example is shown in WO 96/33379 A1 incorporated herein by way of reference. Alternatively, the scheme 2 may involve one or more other, further or separate refrigerant circuits to provide other, further or separate cooling to one or more of the streams. The present invention is not limited by the nature of arrangement of the refrigerant circuit or circuits.

The scheme 2 shown in Figure 2 provides the ability to select one or more of the overhead gaseous streams and liquid bottom streams, and/or parts thereof, both from the refrigerant gas/liquid separators and the other gas/liquid separators, so as to refine the nature of the mixed refrigerant 100 at one or more suitable locations around the refrigerant circuit 4 to best match the requirements of the hydrocarbon cooling process. These requirements can change over time and/or location.

For example, the ambient temperature around a hydrocarbon liquefaction process or plant may require refinement of the particular proportions of the components of the mixed refrigerant to affect greater

and/or lower degrees of cooling in the first heat exchanger(s) and/or in the second heat exchanger(s). In another example, the hydrocarbon cooling process can be started up using only a part of a hydrocarbon feed stream
5 10 in the mixed refrigerant circuit 4, with heavier hydrocarbons being provided into the mixed refrigerant 100 by one or more of the heavier hydrocarbon part streams, such as the part stream 30c from the gas/liquid separator B, so as to enhance the heavier hydrocarbon
10 proportions of the mixed refrigerant 100 during the start-up procedure.

In the scheme 2, it is also possible to remove, such as vent, at least a fraction of the mixed refrigerant 100 as a gaseous overhead refrigerant stream or as a liquid
15 bottom refrigerant stream from a heat exchanger itself. Figure 2 shows two gaseous overhead vent streams 190a, 190b and two liquid vent bottom refrigerant streams 180a, 180b from the first and second heat exchangers 12, 22 respectively. Removal of one of the vent streams 180a,
20 180b, 190a, 190b can also be used to change the component inventory of the mixed refrigerant 100.

As the present invention can be self-sufficient in supplying the components to, and changing the composition of, the mixed refrigerant without the need of a
25 fractionation column, it is particularly suitable where there is limitation of the space available for a hydrocarbon cooling process, either as a stand-alone process, or as part of a larger process or plant such as including one or more pre-treatment processes, post-
30 liquefaction processes, and/or storage of a liquefied hydrocarbon stream including the requirement for one or more storage tanks.

Thus, the present invention is particularly suitable for location on a floating vessel or an off-shore platform, e.g. in the form of a caisson. A floating vessel may be any movable or moored vessel, generally at least having a hull, and usually being in the form of a ship such as a 'tanker'. Examples of such a floating vessel provided with a hydrocarbon liquefaction apparatus are shown and described in for instance WO 2007/064209 and WO 2008/006842.

Such floating vessels can be of any dimensions, but are preferably elongate. Whilst the dimensions of a floating vessel are not limited at sea, building and maintenance facilities for floating vessels may limit such dimensions. Thus, in one embodiment of the present invention, the floating vessel or off-shore platform is less than 600m long such as 500m, and a beam of less than 100m, such as 80m, so as to be able to be accommodated in existing ship-building and maintenance facilities.

An off-shore platform may also be movable, but is generally more-permanently locatable than a floating vessel. An off-shore platform may also float, and may also have any suitable dimensions.

In another embodiment of the present invention, the method is for liquefying natural gas to provide liquefied natural gas.

Preferably, the liquefied hydrocarbon stream provided by the present invention is stored in one or more storage tanks, which storage tanks maybe also located on any floating vessel or off-shore platforms.

Figure 3 shows a floating vessel 52 such as a tanker, including a hydrocarbon liquefying process based on scheme 2 shown in Figure 2. In Figure 3, a hydrocarbon feed stream 10 passes through a first cooling stage 12a

having one or more first heat exchanger(s) 12 such as shown in Figure 2, to provide a partially liquefied hydrocarbon stream 20/30, which passes through a second cooling stage 22c involving one or more second heat exchangers to provide a liquefied hydrocarbon stream 50. The liquefied hydrocarbon stream 50 passes via a cryogenic turbo-expander 53 into an end gas/liquid separator J, to provide an overhead gaseous stream 60, and a liquid bottom stream 70 which passes into a storage tank 42 such as an LNG storage tank 42.

Figure 3 also shows a cooled refrigerant stream 120 similar to that in Figure 2, from the second cooling stage 22c, which passes into the refrigerant gas/liquid separator A also shown in Figure 2. The gas/liquid separator A provides an gaseous overhead refrigerant stream 121, a fraction of which passes through a valve to provide a gaseous stream 123 which can be combined with the gaseous overhead stream 60 from the end gas/liquid separator J to provide a combined stream 80. To the combined stream 80 could be added any boil-off gas from the storage tank 42 passing along line 75 to create a further combined stream 80a which can be compressed and subsequently used as a fuel stream 90. The arrangement shown in Figure 3 provides a method of using any fraction of the gaseous overhead refrigerant stream 121 from the usually coldest refrigerant gas/liquid separator A without requiring additional CAPEX.

Table I gives an overview of estimated compositions and phases of some of the gaseous overhead streams and liquid bottom streams from the gas/liquid separators of an example process of Figure 2. An assumption has been made that liquefaction is performed just below the cricondenbar, and that the temperature of the hydrocarbon

stream at the bundle break in the second heat exchanger 22 supplying line 40 is -45 °C such that the hydrocarbon stream is in the two-phase regime.

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TABLE 1

Separator	Stream	Phase	N2	C1	C2	C3	iC4	nC4
A	121/123	V	81.22%	18.77%	0.01%	0.00%	0.00%	0.00%
	122	L	10.69%	68.35%	18.32%	2.51%	0.08%	0.05%
B	30a	V	1.00%	90.99%	4.99%	1.99%	0.49%	0.49%
	30b/30c	L	0.28%	60.01%	11.96%	12.23%	5.99%	7.82%
C	131/133	V	33.20%	66.13%	0.67%	0.01%	0.00%	0.00%
	132	L	0.73%	27.91%	45.96%	22.22%	1.71%	1.47%
D	111	V	16.85%	64.01%	16.73%	2.30%	0.07%	0.04%
	112/115	L	2.80%	30.38%	43.06%	20.79%	1.60%	1.38%

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TABLE 1 (cont'd)

E	102	V	5.74%	37.41%	37.54%	16.93%	1.28%	1.10%
	103	L	1.12%	13.90%	37.08%	37.65%	5.00%	5.26%
F	40a	V	1.04%	92.07%	4.63%	1.60%	0.33%	0.31%
	40b	L	1.00%	90.95%	5.00%	2.00%	0.50%	0.50%
G	151/153	V	8.37%	63.16%	24.37%	3.88%	0.14%	0.09%
	152	L	0.29%	10.08%	41.65%	38.32%	4.75%	4.90%
H	141	V	6.94%	40.30%	35.30%	15.34%	1.15%	0.99%
I	161	V	1.61%	18.71%	38.84%	32.72%	4.00%	4.12%
J	60	V	11.70%	88.29%	0.01%	0.00%	0.00%	0.00%
	70	L	0.44%	91.09%	5.26%	2.10%	0.53%	0.53%

From Table 1, the different component proportions of various streams or part streams shown in the example scheme 2 of Figure 2 can be seen. For example, the part stream 123 from the gaseous overhead refrigerant stream 121 from the coldest refrigerant gas/liquid separator A has a high nitrogen proportion, and the removal of this part stream 123 from the mixed refrigerant 100 will decrease the nitrogen inventory of the overall mixed refrigerant 100. Stream 190b would also be a good place to remove light components from the mixed refrigerant. Heavy components may be removed from the mixed refrigerant inventory by removing at least a part of either one of the liquid vent bottom refrigerant streams 180a, 180b from the first and second heat exchangers 12, 22 respectively, or by removing a portion of the inter-cooled bottom refrigerant stream 203 from separator K if such is provided. These streams, and in particular stream 203 are expected to have the highest molecular weight in the refrigerant circuit.

The part stream 30c from the first gas/liquid separator B has relatively high C₃ and C₄ proportions, whose addition to the mixed refrigerant stream will generally increase its inventory of C₃ and the C₄s.

By use of one or more of the streams shown in Table 1 and other streams mentioned above, either by its addition to or removal from the mixed refrigerant 100, and the proportion of such addition and/or removal, allows refinement of the component inventory of the mixed refrigerant 100 to suit specific requirements or changing conditions. In this way, the hydrocarbon liquefying process can be self-sufficient in refining the component proportions of the mixed refrigerant, reducing and/or removing the need for separate sources, in particular

separate storage, of each component of the mixed refrigerant. For example, separate storage tanks for propane and butane are not required, allowing the hydrocarbon liquefying process to be located in a smaller area, increasing safety by the reduction and/or removal of high-risk gas storages.

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 appended claims.

Applicants also propose that the methods and apparatuses described above, wherein the refrigerant portion is provided by partially liquefying the hydrocarbon feed stream and separating the mixed C_2^+ , represent merely one way of obtaining a refrigerant portion to change the mixed refrigerant inventory. Moreover, applicants propose that the methane-enriched gaseous overhead stream is merely one example of the stream that can be liquefied by the at least the fraction of the mixed refrigerant circulating in the mixed refrigerant circuit.

Defined more broadly, the present invention provides a method of liquefying a hydrocarbon stream, comprising at least the steps of:

- (A) providing a hydrocarbon feed stream;
- (B) drawing from the hydrocarbon feed stream a refrigerant portion;
- (C) circulating a mixed refrigerant through a mixed refrigerant circuit;
- (D) adding, without fractionation, at least a part of the refrigerant portion to the mixed refrigerant circuit to change the inventory of the mixed refrigerant in the mixed refrigerant circuit; and

(E) cooling and liquefying a part of the hydrocarbon feed stream not comprised in the refrigerant portion of step (B) by heat exchanging against at least a fraction of the mixed refrigerant circulating in the mixed refrigerant circuit, to provide a liquefied hydrocarbon stream.

In the embodiments discussed above with reference to Figs. 1 and 2, the refrigerant portion of step (B) is provided in the form of the mixed C_2^+ enriched stream 30c, while the part of the hydrocarbon feed stream to be cooled and liquefied in step (E) that does not form part of the refrigerant portion is provided in the form of the methane-enriched stream 30a and/or stream 30.

Other ways of providing the refrigerant portion, include drawing (e.g. by means of a divider) a portion of the feed stream upstream of any liquefaction, such as e.g. from line 10 upstream of the one or more first heat exchangers, to provide a stream which may be used to form the refrigerant portion of step (B). Of course, the not-liquefied portion of the feed stream may be partially liquefied after having been drawn from the feed stream, to provide a C_2^+ enriched liquid bottom stream that can be used to form the refrigerant portion. This has as advantage that excess methane and other light components are removed before adding to the mixed refrigerant inventory in the refrigerant circuit.

However, the refrigerant portion may alternatively be formed without forming the mixed C_2^+ enriched liquid bottom stream. This has an advantage that the mixed C_2^+ enriched stream does not have to be formed and that therefore no gas/liquid separator needs be supplied for that purpose. Clearly, the molecular weight of the

refrigerant portion used to change the refrigerant inventory would be then be lower than that of the mixed C_2^+ enriched liquid bottom stream from the separator. In embodiments that use the composition of the feed gas in line 10 to add to the refrigerant inventory, without first partly liquefying and gas/liquid separating the feed gas, this may therefore result in adding more of the light components to the refrigerant circuit than needed to obtain a target composition. Like in any other embodiment described herein, such light components may subsequently be removed via e.g. line 190b or 123, to achieve that the remaining refrigerant inventory meets the target composition. This may require first liquefying the part of the hydrocarbon feed stream that is not comprised in the refrigerant portion using a sub-optimal mixed refrigerant inventory that has a composition that is off the target composition. The final target refrigerant composition may then be obtained via an iterative process over time of feeding streams to the refrigerant circuit and/or removing selected parts of the refrigerant from the refrigerant circuit.

Part of the hydrocarbon feed gas that is not used to form the refrigerant portion may be subjected to the cooling and liquefying of step (E). This may be done simultaneously to steps (B) and (D), such as in the embodiments explained above with reference to Figs. 1 and 2, but it may also be done later in time.

In the latter case, the removal of the refrigerant portion in step (B), and the steps (C) and (D) are performed earlier in time than step (E). This would be an attractive option for instance during starting up of the process and making up the refrigerant inventory for the first time. Also in such embodiments, steps (f), (g), and

(h) as defined hereinabove or any other way to remove one or more fractions of the mixed refrigerant from the mixed refrigerant circuit described herein may be applied to change the component inventory of the mixed refrigerant to change the component inventory.

In any of the embodiments, the circulating of the mixed refrigerant through the mixed refrigerant circuit in step (c) may comprise compressing a vaporous fraction of the mixed refrigerant though at least to stages of compression, and subsequently passing the compressed mixed refrigerant though one or more coolers. This may be taken advantage of when removing heavy components from the mixed refrigerant in the mixed refrigerant stream as follows:

- drawing an inter-stage compressed mixed refrigerant stream from a first one of the at least two stages of compression;
- intercooling the inter-stage compressed mixed refrigerant stream;
- passing the intercooled mixed refrigerant through one or more intercooler refrigerant gas/liquid separator to provide one or more gaseous overhead refrigerant streams and one or more liquid bottom refrigerant streams;
- feeding the one or more gaseous overhead refrigerant streams to a second one of the at least two stages of compression; and
- removing at least a part of the liquid bottom refrigerant stream to change the component inventory of the mixed refrigerant circuit.

At any time that no full liquefaction of any part of the hydrocarbon feed gas is pursued, as e.g. during starting up of the process, it is an option to use any of the refrigerant gas/liquid separators provided in the

refrigerant circuit, such as refrigerant gas/liquid separator D, as the first gas/liquid separator to provide the methane-enriched gaseous overhead stream and a mixed C₂⁺ bottom stream. The refrigerant gas/liquid separator so used should be bypassed with a refrigerant bypass line in order to allow the refrigerant to be circulated. The refrigerant inventory can then be changed using the principles set forth herein based on these streams.

C L A I M S

1. A method of liquefying a hydrocarbon stream,
comprising at least the steps of:

(a) partially liquefying a hydrocarbon feed stream to
provide a partially liquefied hydrocarbon stream;

5 (b) passing the partially liquefied hydrocarbon stream
through a first gas/liquid separator to provide a
methane-enriched gaseous overhead stream and a mixed C_2^+
enriched liquid bottom stream;

10 (c) circulating a mixed refrigerant through a mixed
refrigerant circuit;

(d) adding, without fractionation, at least a part of
the mixed C_2^+ enriched bottom stream to the mixed
refrigerant circuit to change the C_2^+ component inventory
of the mixed refrigerant in the mixed refrigerant
15 circuit; and

(e) liquefying the methane-enriched gaseous overhead
stream by heat exchanging against at least a fraction of
the mixed refrigerant circulating in the mixed
refrigerant circuit, to provide a liquefied hydrocarbon
20 stream.

2. Method as claimed in Claim 1, wherein the
hydrocarbon feed stream is partially liquefied in step
(a) by passage through one or more first heat exchangers
and wherein the methane-enriched gaseous overhead stream
25 is liquefied in step (e) by passage through one or more
second heat exchangers.

3. Method as claimed in Claim 2, wherein
the methane-enriched gaseous overhead stream is partially
liquefied during passage of through the one or more of
30 the second heat exchangers to form a further partially

liquefied hydrocarbon stream, the method further comprising passing the further partially-liquefied hydrocarbon stream through a second gas/liquid separator to provide a second methane-enriched gaseous overhead stream, and a second liquid bottom stream; and using at least a part of the second liquid bottom stream to change the component inventory of the mixed refrigerant circuit.

4. Method as claimed in one or more of the preceding claims, further comprising the steps of:

(f) passing one or more fractions of the mixed refrigerant through one or more heat exchangers to provide one or more cooled mixed refrigerant streams;

(g) passing at least one of the cooled mixed refrigerant streams through one or more refrigerant gas/liquid separators to provide one or more gaseous overhead refrigerant streams and one or more liquid bottom refrigerant streams; and

(h) removing at least a part of at least one of the gaseous overhead refrigerant streams and the liquid bottom refrigerant streams to change the component inventory of the mixed refrigerant circuit.

5. Method as claimed in one or more of the preceding claims, wherein one or more fractions of the mixed refrigerant are removed from the mixed refrigerant circuit to change the component inventory of the mixed refrigerant.

6. Method as claimed in claim 5, wherein the component inventory of at least one stream added to the mixed refrigerant circuit is different from the component inventory of at least one fraction of the mixed refrigerant being removed from the same mixed refrigerant circuit.

7. Method as claimed in any one of the preceding claims, wherein said partially liquefying in step (a) comprises passing the hydrocarbon feed stream against at least a first fraction of the mixed refrigerant in the mixed refrigerant circuit in one or more first heat exchangers, to provide the partially liquefied hydrocarbon stream of step (a), preferably at a temperature below 0°C.

8. Method as claimed in claim 7, wherein

the first fraction of the mixed refrigerant in the first heat exchanger(s) also provides an at least partly evaporated mixed refrigerant stream; the method further comprising:

passing the at least partly evaporated mixed refrigerant stream through a second refrigerant gas/liquid separator to provide a gaseous overhead refrigerant stream and a liquid bottom refrigerant stream; and

removing at least a part of the liquid bottom refrigerant stream from the mixed refrigerant circuit to change the component inventory of the mixed refrigerant.

9. Method as claimed in one or more of claims 2 to 8, further comprising:

at least partially evaporating at least one of the fractions of the mixed refrigerant(s) in the first and second heat exchangers to provide at least one of a liquid refrigerant bottom stream and at least one gaseous refrigerant overhead stream from at least one of the first and second heat exchangers; and

removing at least a part of at least one of the gaseous refrigerant overhead streams and the liquid refrigerant bottom streams to change the component inventory of the mixed refrigerant circuit.

10. Method as claimed in one or more of the preceding claims, wherein the mixed refrigerant comprises two or more of the group comprising: nitrogen, methane, ethane, ethylene, propane, propylene, butanes, pentanes.

5 11. Method as claimed in one or more of the preceding claims, wherein the hydrocarbon feed stream comprises, preferably essentially consists of natural gas, and wherein the liquefied hydrocarbon stream is LNG.

12. Method as claimed in any one of the preceding
10 claims, further comprising:

passing the liquefied hydrocarbon stream through an end flash valve and an end gas/liquid separator, to provide a gaseous overhead stream and a liquid bottom stream; and

15 combining the gaseous overhead stream from the end gas/liquid separator and at least a part of the gaseous overhead refrigerant stream from one of the refrigerant gas/liquid separators, to provide a combined stream for compression and use as a fuel gas.

20 13. Method as claimed in one or more of the preceding claims wherein the mixed refrigerant is initially formed of natural gas from which the C_5^+ components have been removed.

25 14. Method as claimed in one or more of the preceding claims, performed on a floating vessel or off-shore platform.

15. Apparatus for liquefying a hydrocarbon stream, the apparatus at least comprising:

30 one or more first heat exchangers for partially liquefying a hydrocarbon feed stream to provide a partially liquefied hydrocarbon stream;

a first gas/liquid separator (B) through which the partially liquefied hydrocarbon stream can pass to

provide a methane-enriched gaseous overhead stream and a mixed C_2^+ enriched liquid bottom stream;

a mixed refrigerant circuit comprising a mixed refrigerant;

5 one or more lines to pass at least a part of the mixed C_2^+ bottom stream into the mixed refrigerant circuit, without a fractionator, to change the component inventory of mixed refrigerant; and

10 one or more second heat exchangers to liquefy the methane-enriched gaseous overhead stream using at least a fraction of the mixed refrigerant to provide a liquefied hydrocarbon stream.

16. A floating vessel or an off-shore platform having an apparatus as defined in claim 15.

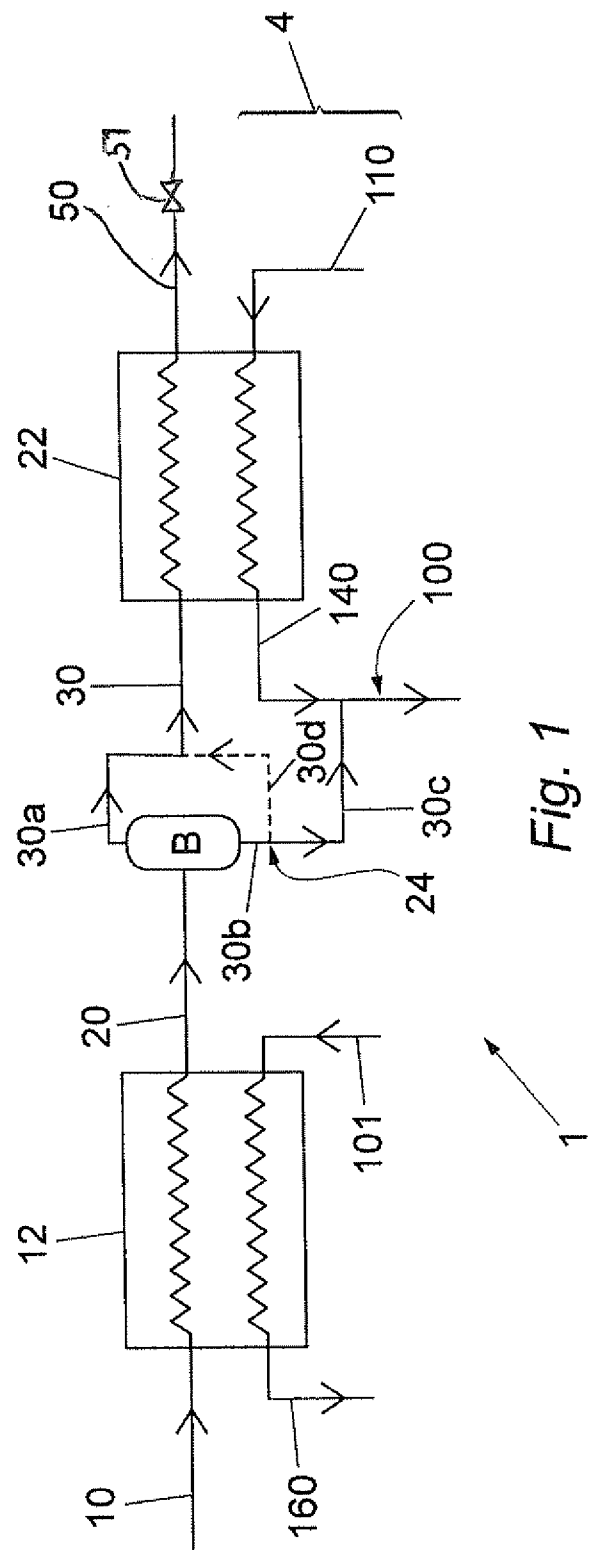
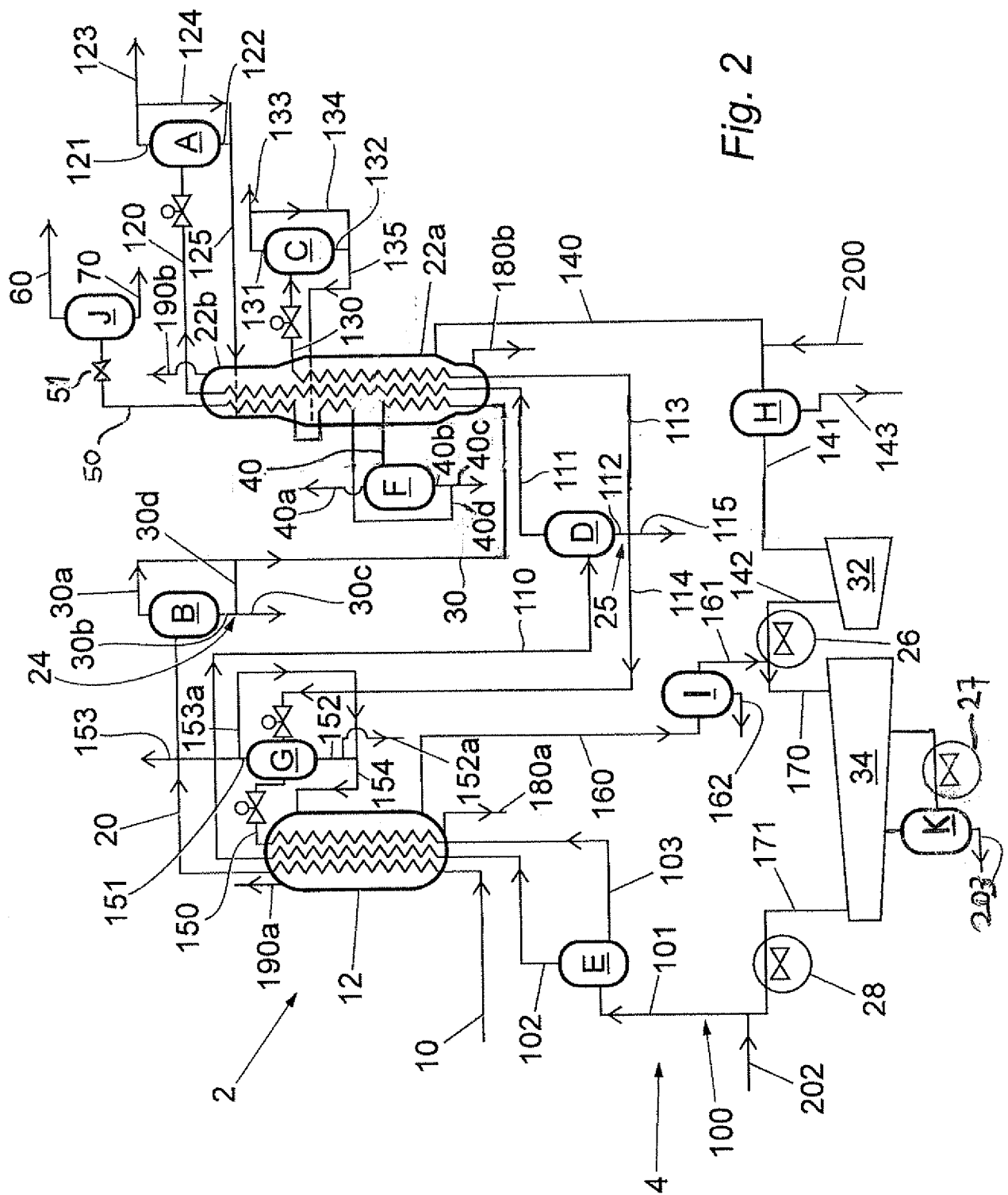


Fig. 1



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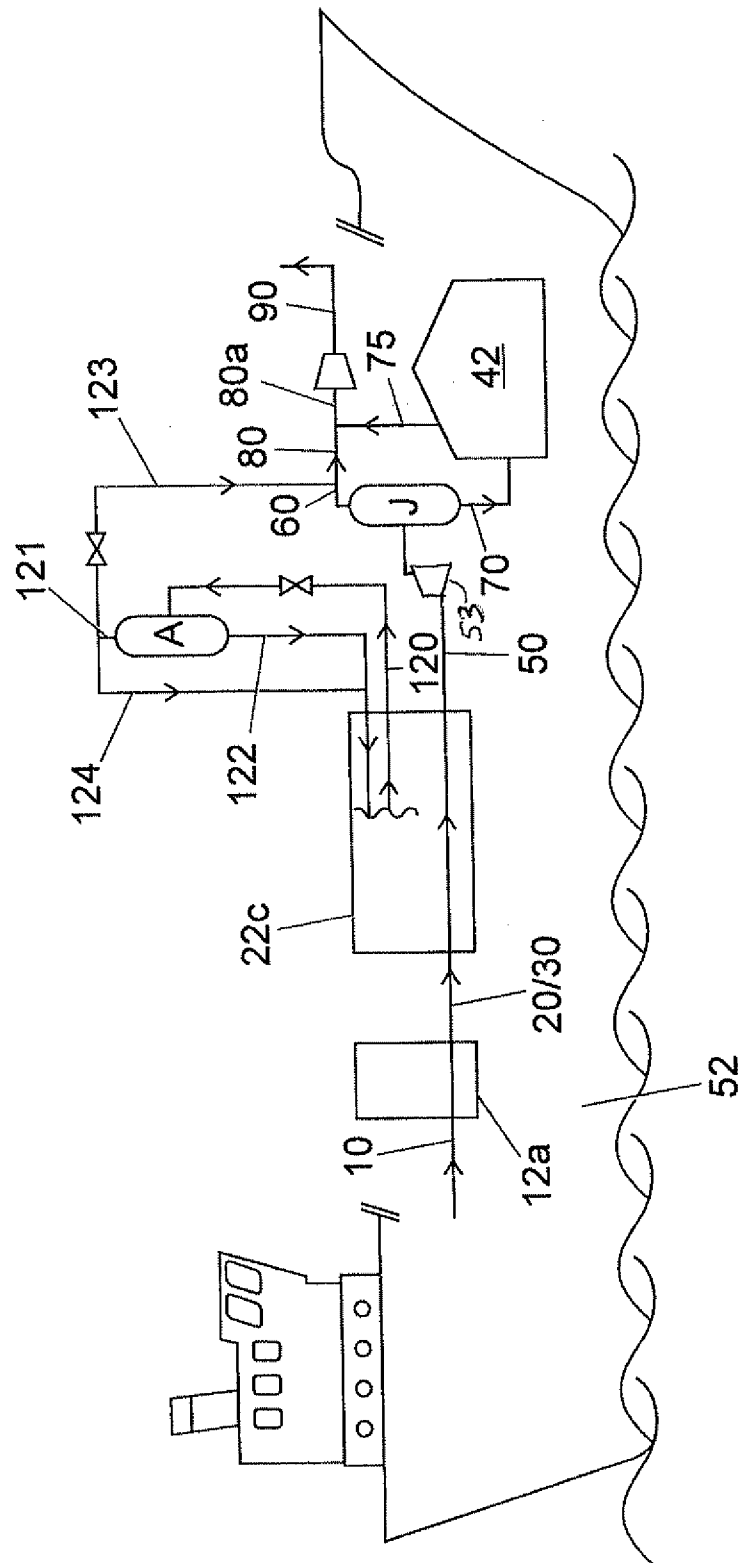


Fig. 3