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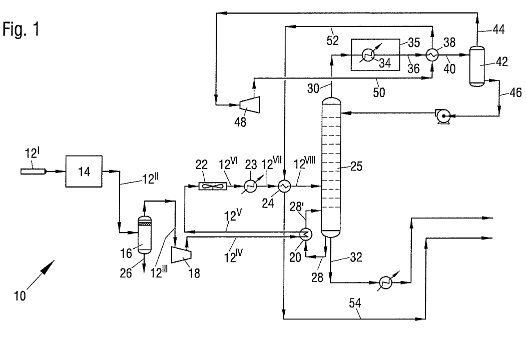
(54) **PLANT AND METHOD FOR SEPARATING LIQUIFIED PETROLEUM GAS FROM FUEL GAS BY CRYOGENIC DISTILLATION**

(57) The present invention relates to a plant for separating a feed composition comprising methane and C_{2+}-hydrocarbons into a methane depleted fraction as product composition and into a methane enriched fraction, in particular for separating liquified petroleum gas from fuel gas, wherein the plant comprises:
a) a distillation column comprising an inlet line, an overheads outlet line for the methane enriched fraction and a bottom outlet line for the methane depleted fraction,
b) a condenser for condensing a portion of the methane enriched fraction so as to produce a mixed-phase effluent comprising a condensed phase and a vapor phase, wherein the condenser is directly or indirectly connected with the overheads outlet line of the distillation column,
c) a gas-liquid separator for the partially condensed methane enriched fraction being connected with the condenser, wherein the gas-liquid separator comprises an outlet line for gas and an outlet line for liquid, wherein the outlet line for liquid is connected with the distillation column, and
d) a turboexpander being connected with the outlet line for gas of the gas-liquid separator and comprising an outlet line for expanded gas, wherein the outlet line for expanded gas is directly or indirectly connected with the condenser so as to cool the methane enriched fraction within the condenser using the expanded gas as cooling agent, wherein the condenser further comprises an outlet line for withdrawing the expanded gas from the condenser.

Fig. 1



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Description

[0001] The present invention relates to a plant and a method for separating in general a feed composition comprising methane and C_{2+}-hydrocarbons into a methane depleted fraction as product composition and into a methane enriched fraction as well as specifically to a plant and a method for separating liquified petroleum gas from fuel gas by cryogenic distillation.

[0002] Refinery fuel gas is generated during the petroleum refinery process and is a gas mixture consisting essentially of short-chain hydrocarbons, namely mainly of methane and smaller amounts of ethane, propane and butane. In addition to short-chain hydrocarbons, refinery fuel gas may contain non-hydrocarbons, such as hydrogen, nitrogen, carbon monoxide, carbon dioxide or the like, and small amounts of larger-chain hydrocarbons. On account of its high heating value, refinery fuel gas has been combusted for decades for instance in the refinery plant itself, such as in process heaters, in turbines or the like. However, in the last years it became more and more common to first separate mainly valuable C_{2-4}-hydrocarbons and in particular C_{3-4}-hydrocarbons from the refinery fuel gas so as to obtain a methane depleted C_{2-4}-hydrocarbon-rich fraction and a methane enriched fraction. While the methane enriched fraction is used for combustion, as usual, the methane depleted C_{2-4}-hydrocarbon-rich fraction or C_{3-4}-hydrocarbon-rich fraction, respectively, is used - if necessary after further separation and purification steps - for other applications. Examples for such other applications are for instance the use as raw material for chemical syntheses or in form of liquified petroleum gas (LPG) - which essentially consists of C_{3-4}-hydrocarbons and C_2-hydrocarbons - as cooling agent, as fuel for homes or the like. This separation of a C_{2-4}-hydrocarbon-rich fraction or of a C_{3-4}-hydrocarbon-rich fraction, respectively, from refinery fuel gas has also environmental benefits. More specifically, methane has a higher upper heating value and leads to lower specific carbon dioxide emissions during combustion compared to the ingredients of C_{2-4}-hydrocarbons or liquified petroleum gas, respectively. This is nowadays a particular advantage, since it helps industrial companies to reduce carbon emissions and thus to improve their environmental social and governance scores.

[0003] It is known to separate a C_{2-4}-hydrocarbon-rich fraction or a C_{3-4}-hydrocarbon-rich fraction from refinery fuel gas by absorption and/or distillation. More specifically, it is known to separate liquified petroleum gas from refinery fuel gas by cryogenic distillation. Such a method comprises the distillation of refinery fuel gas at a low temperature and at a high pressure so as to obtain as overheads fraction a methane enriched fraction and as bottom fraction a methane depleted fraction, which is in fact a C_{2-4}-hydrocarbon-rich fraction and in particular a C_{3-4}-hydrocarbon-rich fraction or liquefied petroleum gas, respectively. However, the known plants and processes for separating a feed composition comprising methane and C_{2+}-hydrocarbons by cryogenic distillation into a methane depleted fraction as product composition and into a methane enriched fraction and specifically for separating liquified petroleum gas from fuel gas by cryogenic distillation are in need of improvement, since they require during the operation a comparable high amount of energy and thus have high operational expenses (OPEX).

[0004] In view of this, the object underlying the present invention is to provide a plant and a method for separating in general a feed composition comprising methane and C_{2+}-hydrocarbons into a methane depleted fraction as product composition and into a methane enriched fraction and specifically to provide a plant and a method for separating liquified petroleum gas from fuel gas by cryogenic distillation, which have a reduced energy demand during operation, but nevertheless an excellent separation efficiency.

[0005] In accordance with the present invention this object is satisfied by providing a plant for separating a feed composition comprising methane and C_{2+}-hydrocarbons into a methane depleted fraction as product composition and into a methane enriched fraction, in particular for separating liquified petroleum gas from (refinery) fuel gas, wherein the plant comprises:

a) a distillation column comprising an inlet line, an overheads outlet line for the methane enriched fraction and a bottom outlet line for the methane depleted fraction,

b) a condenser for condensing a portion of the methane enriched fraction so as to produce a mixed-phase effluent comprising a condensed phase and a vapor phase (subsequently also referred to as "partially condensed methane enriched fraction"), wherein the condenser is directly or indirectly connected with the overheads outlet line of the distillation column,

c) a gas-liquid separator for the partially condensed methane enriched fraction being connected with the condenser, wherein the gas-liquid separator comprises an outlet line for gas and an outlet line for liquid, wherein the outlet line for liquid is connected with the distillation column, and

d) a turboexpander being connected with the outlet line for gas of the gas-liquid separator and comprising an outlet line for expanded gas, wherein the outlet line for expanded gas is directly or indirectly connected with the condenser so as to cool the methane enriched fraction within the condenser using the expanded gas as cooling agent, wherein the condenser further comprises an outlet line for withdrawing the expanded gas from the condenser.

[0006] This solution bases on the surprising finding that the energy demand for the separation of a feed composition comprising methane and C_{2+}-hydrocarbons into a methane depleted fraction as product composition and into a methane enriched fraction, such as preferably the separation of liquified petroleum gas from fuel gas, by cryogenic distillation can be drastically reduced for a given separation degree, if the methane enriched fraction obtained as overheads fraction during the cryogenic distillation is cooled and partially condensed in a condenser so as to produce a mixed-phase effluent comprising a condensed phase and a vapor phase or partially condensed methane enriched fraction, respectively, then separated into the liquid fraction and the gas fraction, whereas the liquid fraction is returned as reflux into the distillation column, whereas the gas fraction of the methane enriched fraction is expanded in the turboexpander and then used as cooling agent in the condenser. It has been found by the inventors that it is important to use for the condenser the cold expanded gas obtained in the turboexpander as cooling agent, in order to achieve a suitably low temperature at the overheads of the condenser and to thereby obtain a sufficiently high separation of liquefied petroleum gas from the fuel gas. Moreover, the arrangement of the gas-liquid separator upstream of the turboexpander helps to decrease the energy demand for operating the plant, because the liquid fraction of the methane enriched fraction being condensed in the condensers does not need to be processed in the turboexpander, but only the gas fraction of the methane enriched fraction. This does not exclude that downstream of the turboexpander a further gas-liquid separator is arranged; however, it is important that one gas-liquid separator is arranged upstream of the turboexpander and that the liquid fraction obtained therein is recycled into the distillation column.

[0007] Separating a feed composition comprising methane and C_{2+}-hydrocarbons into a methane depleted fraction as product composition and into a methane enriched fraction means in accordance with the present invention that the methane depleted fraction contains - on a percentage basis - less methane than the feed composition and that the methane enriched fraction contains more methane than the feed composition.

[0008] As set out above, the condenser for condensing a portion of the methane enriched fraction so as to produce a mixed-phase effluent comprising a condensed phase and a vapor phase may be connected with the overheads outlet line of the distillation column directly or indirectly. In accordance with a particularly preferred embodiment of the present invention, the condenser is indirectly connected with the overheads outlet line of the distillation column. More specifically, it is particularly preferred that a pre-condenser for condensing a portion of the methane enriched fraction is arranged between the overheads outlet line of the distillation column and the condenser, wherein the pre-condenser is connected with the overheads outlet line of the distillation column and the condenser is connected with the pre-condenser. It has been found by the inventors that it is advantageous that two condensers are provided in series upstream of the gas-liquid separator and of the turboexpander and to use for the condenser the cold expanded gas obtained in the turboexpander as cooling agent, in order to achieve a particular suitably low temperature at the overheads of the condenser and to thereby obtain a sufficiently high separation of liquefied petroleum gas from the fuel gas. Thereby, the energy demand for the separation of a feed composition comprising methane and C_{2+}-hydrocarbons into a methane depleted fraction as product composition and into a methane enriched fraction, such as preferably the separation of liquified petroleum gas from fuel gas, by cryogenic distillation can be further reduced for a given separation degree.

[0009] In principle, the present invention is not particularly limited concerning the kind of the pre-condenser. However, good results are in particular obtained, when the pre-condenser is part of a single-stage vapor compression refrigeration unit. This allows to energy-efficiently cool the methane enriched fraction obtained as overheads fraction of the distillation column.

[0010] More specifically, the pre-condenser preferably is part of a single-stage vapor compression refrigeration unit, which comprises two heat exchangers, a throttle and a compressor, wherein one of the two heat exchangers is the pre-condenser.

[0011] Preferably, a first of the two heat exchangers being the pre-condenser is connected via a vapor line for the cooling agent (or refrigerant, respectively) with the compressor, which in turn is connected via a vapor line for compressed cooling agent with the second heat exchanger. The second heat exchanger preferably further comprises a liquid outlet line for the condensed cooling agent, which is connected via a line with the throttle, which in turn is connected via a liquid/vapor line with the first heat exchanger or pre-condenser, respectively. While the second heat exchanger functions as condenser for the cooling agent, the first heat exchanger functions as evaporator for the cooling agent and as pre-condensor for the methane enriched fraction. In other words, for the cooling agent, the second heat exchanger, which is hotter and releases heat preferably by cooling it with air and/or water, is a condenser and the first heat exchanger or pre-condenser, respectively, which is colder and accepts heat, is an evaporator. At the start of the thermodynamic cycle the cooling agent enters the compressor as a low pressure and low temperature vapor. Then, the pressure of the vapor is increased and the cooling agent leaves the compressor as a higher temperature and higher pressure superheated gas. This hot pressurized gas of the cooling agent then passes through the second heat exchanger or condenser, respectively, where it releases heat to the surroundings as it cools and condenses completely. The cooler high-pressure liquid of the cooling agent then passes through the throttle or Joules Thomson throttle valve, which is in fact an expansion valve, which reduces the pressure of the cooling agent abruptly and thereby causes that the temperature of the cooling agent drops drastically. The cold low-pressure mixture of liquid and vapor of the cooling agent then travels through the first heat exchanger or pre-condenser, respectively, or evaporator, respectively, where the cooling agent vaporizes completely as it accepts heat from the surroundings before it returns to the compressor as a low pressure low temperature gas to start the cycle again. The methane enriched fraction is led through the first heat exchanger and the first heat exchanger is for the methane enriched fraction the pre-condenser, in which the methane enriched fraction is cooled and thereby partially condensed by the cold low-pressure mixture of liquid and vapor of the cooling agent traveling through the first heat exchanger. For instance, the two heat exchangers of the pre-condenser are shell and tube heat exchangers. The cooling agent may be led through the tubes of both heat exchangers or through the shells of both heat exchangers. Preferably, the cooling agent is led through the tubes of both heat exchangers and the methane enriched fraction is led through the shell of the first heat exchanger. The shell of the second heat exchanger may be cooled by air, water or any other medium. Alternatively, a brazed aluminum heat exchanger as well as cold box may be used for the first heat exchanger, which are more energy efficient, but involve higher costs.

[0012] In an alternative embodiment, the throttle or Joules Thomson throttle valve, respectively, of the single-stage vapor compression refrigeration unit is replaced by an expander. This increases the capital costs for the plant, but reduces the operating costs by recovering energy from the expander. A Joules Thomson throttle valve provides for pressure let down, but does not enable recovery of energy, as with an expander, to reduce operating costs. An expander can be used to partially drive a compressor and can be used to generate electricity. In addition, an expander can be designed to be close to constant entropy operation whereas, Joules Thomson throttle valve follows constant enthalpy. The difference in stream enthalpy enables additional cooling across the evaporator for an expander compared to a Joules Thomson throttle valve.

[0013] As set out above, it is preferred that the condenser for condensing a portion of the methane enriched fraction is connected with the pre-condenser. In this embodiment, the pre-condenser comprises an inlet line for the methane enriched fraction obtained as overheads fraction of the distillation column, wherein the inlet line is connected with the overheads outlet line of the distillation column. Furthermore, the pre-condenser comprises an outlet line for the pre-condensed methane enriched fraction, wherein the outlet line is connected with an inlet line of the condenser. The condenser is called condenser, even if the optional, but preferred, pre-condenser is in fact also a condenser.

[0014] Preferably, the condenser is a shell and tube condenser. The methane enriched fraction to be cooled and partially condensed may be led through the tubes and the expanded gas generated in the turboexpander may be led through the shell of the condenser or the methane enriched fraction to be cooled and partially condensed may be led through the shell and the expanded gas generated in the turboexpander may be led through the tubes of the shell and tube condenser. Preferably, the methane enriched fraction is led through the tubes and the expanded gas generated in the turboexpander is led through the shell of the shell and tube condenser. Alternatively, a brazed aluminum heat exchanger as well as cold box may be used for the condenser, which are more energy efficient, but involve higher costs.

[0015] In accordance with the present invention, the gas-liquid separator for the partially condensed methane enriched fraction is connected with the condenser, which means that the condenser comprises an outlet for the methane enriched fraction having been partially condensed therein and that the gas-liquid separator comprises an inlet line being connected with the outlet line of the condenser for the partially condensed methane enriched fraction having been generated in the condenser. The present invention is not specifically limited concerning the type of gas-liquid separator. For instance, the gas-liquid separator may be a drum or any other kind of a gas-liquid settling vessel. The gas-liquid separator may comprise one or more internals supporting the separation of gas and liquid phases, such as an inlet diffusor, a de-entrainment device or the like. While the outlet line for gas of the gas-liquid separator is connected with the turboexpander, the outlet line for liquid of the gas-liquid separator is connected with the distillation column, in order to reflux the condensed portion of the methane enriched fraction into the distillation column.

[0016] As set out above, it is important that a gas-liquid separator for the partially condensed methane enriched fraction is arranged upstream of the turboexpander (but downstream of the distillation column) and that the condensed fraction of the methane enriched fraction is removed there and refluxed into the distillation column, because this helps to decrease the energy demand for operating the plant. Moreover, the gas-liquid separator assures that all liquid is removed from the methane enriched fraction entering the turboexpander. This is important, because liquid entering a turboexpander can damage the turboexpander. Distillation columns flood for various reasons at unexpected times and when they flood, the overheads fraction includes liquid. Thus, the gas-liquid separator also "buffers" such temporary liquid-carryover of the distillation column in the methane enriched fraction.

[0017] In accordance with the present invention, the outlet line for gas of the gas-liquid separator through which the gas portion of the methane enriched fraction flows, is connected with the turboexpander, in which the methane enriched fraction is fast expanded and thereby drastically cooled, before the expanded and cooled methane enriched fraction is led as cooling agent to the condenser. In principle, the present invention is not particularly restricted concerning the type of the turboexpander, as long as it allows to fast expand and drastically cools the gaseous methane enriched fraction. Good results are for instance achieved, when the turboexpander design follows closely to constant entropy operation.

[0018] The distillation column may be any distillation column being suitable for cryogenic distillation. In order to increase the mass and heat transfer, the distillation column preferably comprises at least one internal element selected from the group consisting of trays, structured packings, random packings and arbitrary combinations of two or more of the aforementioned elements. In addition, where necessary distributors and collectors may be included above and below the one or more internal elements.

[0019] Moreover, it is preferred that the distillation column is designed to be operated so as to have during the operation 15 to 40 theoretical stages and preferably 20 to 30 theoretical stages.

[0020] In a further development of the idea of the present invention, it is proposed that the distillation column does not comprise within the distillation column any cooler and does not comprise within the distillation column any condenser. Such internal coolers and condensers are disadvantageous, because they require costly and difficult maintenance over that of conventional condensing exchangers. Moreover, they are disadvantageous in view of the plant investment costs and the operational costs. Furthermore, such internal coolers and condensers are disadvantageous, because they have an increased distillation column height, if the number of internal stages remain the same, or, if the number of internal stages is reduced so as to maintain the height of the distillation column, then the distillation column with such internal coolers and condensers has a lower separation efficiency. In addition, a further disadvantage thereof is that a more complexed internal design is necessary in order to fit in the condensor and additional equipment for liquid collection and redistribution into the distillation column.

[0021] As set out above, an important feature of the present invention is that the outlet line for expanded gas of the turboexpander is directly or indirectly connected with the condenser so as to cool the methane enriched fraction within the condenser by using the expanded gas of the turboexpander, which is drastically cooled as consequence of the expansion, as cooling agent. This means that the condenser comprises an inlet line for the expanded gas generated by the turboexpander, wherein this inlet line is directly or indirectly connected with the outlet line for expanded gas of the turboexpander.

[0022] In accordance with a particular preferred embodiment of the present invention, the outlet line for expanded gas of the turboexpander is directly connected with the condenser, i.e. there is no further unit, element or device arranged between the beginning of the outlet line for expanded gas of the turboexpander and the inlet line for the expanded gas into the condenser.

[0023] In accordance with an alternative particular preferred embodiment of the present invention, the outlet line for expanded gas of the turboexpander is indirectly connected with the condenser so as to cool the methane enriched fraction within the condenser using the expanded gas as cooling agent, i.e. there is at least one further unit, element or device arranged between the beginning of the outlet line for expanded gas of the turboexpander and the inlet line for the expanded gas into the condenser. It is preferred in this embodiment that the outlet line for expanded gas of the turboexpander is connected with a second gas-liquid separator, which is in turn connected with the condenser. Optional gas-liquid separator(s) upstream of the distillation column are not considered in this numeration. More specifically, the second gas-liquid separator comprises an inlet line being connected with the outlet line for expanded gas of the turboexpander. In addition, the second gas-liquid separator comprises an outlet line for gas and an outlet line for liquid, wherein the outlet line for liquid is connected directly or indirectly with the distillation column so as to reflux the liquid into the distillation column, and wherein the outlet line for gas is connected with the condenser or with an inlet line of the condenser, respectively, so as to cool the methane enriched fraction within the condenser. During the operation, possible liquid being contained in the expanded gas of the methane enriched fraction, which has been generated in the turboexpander, is separated from the gaseous phase of the expanded methane enriched fraction. While the liquid is recycled or refluxed, respectively, into the distillation column, the gaseous phase of the expanded methane enriched fraction is used as cooling agent in the condenser. The outlet line for liquid is preferably connected directly with the distillation column or into the outlet line for liquid of the upstream, i.e. first gas-liquid separator. The provision of the second gas-liquid separator has the advantage that the C_2-hydrocarbon content of the product composition is slightly increased, whereas the C_2-hydrocarbon content of the methane enriched fraction is decreased. However, the provision of the second gas-liquid separator leads to a small increase of the operational costs.

[0024] The second gas-liquid separator may be embodied as the above-mentioned (first) gas-liquid separator. Thus, the second gas-liquid separator may be a drum or any other kind of a gas-liquid settling vessel and it may comprise one or more internals supporting the separation of gas and liquid phases, such as an inlet diffusor, a de-entrainment device or the like.

[0025] In a further development of the idea of the present invention, it is proposed that the plant further comprises upstream of the distillation column one or more coolers and/or one or more heat exchangers and/or one or more compressors and/or one or more other devices, such as a gas-liquid separator, a drying unit or the like. For this purpose the plant preferably comprises a feed line, which means a line being connected with the inlet line of the distillation column and thus feeding the feed composition into the inlet line, but which is connected - before leading into the inlet line - with at least one of the aforementioned elements, i.e. cooler(s), heat exchanger(s), compressor(s) and other device(s).

[0026] Preferably, the feed line is connected with a heat exchanger for cooling the feed, wherein the heat exchanger comprises an inlet line for the feed composition, an inlet line being connected with the outlet line for withdrawing the expanded gas from the condenser functioning as cooling agent in the heat exchanger, an outlet line for the cooling agent and an outlet line for the cooled feed, wherein the outlet line for the cooled feed is connected with the inlet line of the distillation column or forms the inlet line of the distillation column, respectively. During the operation, the cold expanded methane rich fraction being removed from the condenser thus cools the feed composition, before the cold feed composition is led into the distillation column. By using the cold expanded methane rich fraction not only as cooling agent for the condenser, but also as cooling agent for the heat exchanger cooling the feed composition upstream of the distillation column, the operational costs are further decreased.

[0027] Good results are in particular obtained, when the heat exchanger is a shell and tube heat exchanger. The expanded methane rich fraction as the cooling agent may be led through the tubes and the feed composition through the shell of the heat exchanger, or vice versa. Preferably, the expanded methane rich fraction as the cooling agent is led through the shell and the feed composition through the tubes of the heat exchanger. Alternatively, a brazed aluminum heat exchanger as well as cold box may be used for the heat exchanger, which are more energy efficient, but involve higher costs.

[0028] In accordance with a further preferred embodiment of the present invention, the feed line is connected with a first cooler, which is, if the plant comprises the aforementioned heat exchanger, arranged upstream of the heat exchanger. The first cooler may be any kind of cooler, but it is preferably an air cooler. In this embodiment, the first cooler comprises an inlet line being connected with the feed line and an outlet line being connected with the inlet of the heat exchanger for the feed composition, or, if such a heat exchanger is not present, with the inlet line for the feed composition into the distillation column.

[0029] Moreover, it is preferred that the feed line is further connected with a second cooler being arranged downstream of the first cooler and upstream of the heat exchanger, if a heat exchanger is present. The second cooler may be any kind of cooler, but it is preferably a water cooler. In this embodiment, the second cooler comprises an inlet line (which is a section of the feed line) being connected with the outlet line for feed composition of the first cooler (which is another section of the feed line) and an outlet line (which is a section of the feed line) being connected with the inlet for the feed composition of the heat exchanger, or, if such a heat exchanger is not present, with the inlet line for the feed composition into the distillation column.

[0030] In a further development of the idea of the present invention, it is suggested that the distillation column comprises a recirculation line and the plant further comprises a reboiler, wherein the recirculation line is connected with the reboiler and leads from the bottom of the distillation column to a side section of the distillation column. The reboiler is further connected with the feed line (one section of the feed line is the inlet line of the reboiler, whereas another section of the feed line is the outlet line of the reboiler for the feed composition), which is directly or indirectly connected, if at least one cooler is present upstream of the distillation column, with the most upstream thereof, or, if no cooler is present, with the heat exchanger or, if such a heat exchanger is not present, with the inlet line for the feed composition into the distillation column. More specifically, the reboiler comprises an inlet for bottom fraction being connected with the part of the recirculation line deriving from the bottom of the distillation column and an outlet for bottom fraction being connected with the part of the recirculation line leading to the side section of the distillation column. In addition, the reboiler comprises an inlet for feed composition being connected with a section of the feed line and an outlet for feed composition being connected with another section of the feed line arranged downstream thereof and leading, if one or more coolers are present, into the most upstream cooler, or, if no cooler but one or more heat exchangers are present, into the respective inlet of the most upstream heat exchanger, or, if no cooler and no heat exchangers are present, into the inlet line of the distillation column. This embodiment allows to use internal heat of the feed composition to heat the bottom fraction of the distillation column to thereby cool the feed composition and reduce the reboiler heating medium utility cost.

[0031] In accordance with still a further preferred embodiment of the present invention, the feed line is connected with a gas-liquid separator. Since this gas-liquid separator is located upstream of the distillation column, it is not considered for the numeration (first, second and so on) of the gas-liquid separator(s) being arranged downstream of the distillation column. The gas-liquid separator comprises a section of the feed line as inlet line for the feed composition, an outlet line for liquid and an outlet line for gas, wherein the outlet line for gas is connected with a compressor for compressing the feed composition. The compressor comprises a section of the feed line as outlet line, which is directly or indirectly connected, if a reboiler is present, with the inlet for feed composition of the reboiler, or, of no reboiler is present, with the most upstream cooler, if at least one cooler is present upstream of the distillation column, or, if no cooler is present, with the heat exchanger or, if such a heat exchanger is not present, with the inlet line for the feed composition into the distillation column.

[0032] In addition, it is preferred that the feed line is connected with a pretreatment unit, which preferably comprises a molecular sieve or a dryer. The pretreatment unit comprises a section of the feed line as outlet line, which is directly or indirectly connected with the inlet line for the feed composition of the gas-liquid separator being upstream of the distillation column, or, if such a gas-liquid separator is not present, with the inlet for feed composition of the reboiler, or, of no reboiler is present, with the most upstream cooler, if at least one cooler is present upstream of the distillation column, or, if no cooler is present, with the heat exchanger or, if such a heat exchanger is not present, with the inlet line for the feed composition into the distillation column.

[0033] In a further aspect, the present invention relates to a method for separating a feed composition comprising methane and C_{2+}-hydrocarbons into a methane depleted fraction as product composition and into a methane enriched fraction, wherein the method is performed in the aforementioned plant.

[0034] Thus, the method comprises in accordance with a first embodiment the steps of:

i) introducing feed composition into the distillation column, obtaining at the overheads of the distillation column a methane enriched fraction and obtaining at the bottom of the distillation column a methane depleted fraction,
ii) leading the methane enriched fraction obtained in step i) into the condenser so as to cool and partially condense the methane enriched fraction so as to produce a mixed-phase effluent comprising a condensed phase and a vapor phase (or partially condensed methane enriched fraction, respectively),
iii) leading the partially condensed methane enriched fraction obtained in step ii) into the gas-liquid separator so as to obtain a gaseous methane enriched fraction and a liquid methane enriched fraction, wherein the liquid methane enriched fraction is recycled into the distillation column,
iv) leading the gaseous methane enriched fraction obtained in step iii) into the turboexpander so as to expand and thereby cool the methane enriched fraction and
v) leading the expanded and cooled methane enriched fraction obtained in step v) as cooling agent into and through the condenser and withdrawing the methane enriched fraction from the condenser.

[0035] In accordance with a second preferred embodiment, the method comprises the steps of:

a) introducing feed composition into the distillation column, obtaining at the overheads of the distillation column a methane enriched fraction and obtaining at the bottom of the distillation column a methane depleted fraction,
b) leading the methane enriched fraction obtained in step a) into a pre-condenser so as to cool and partially condense the methane enriched fraction so as to produce a mixed-phase effluent comprising a condensed phase and a vapor phase (or partially condensed methane enriched fraction, respectively),
c) leading the pre-condensed methane enriched fraction obtained in step b) into the condenser so as to cool and partially condense the methane enriched fraction,
d) leading the partially condensed methane enriched fraction obtained in step c) into the gas-liquid separator so as to obtain a gaseous methane enriched fraction and a liquid methane enriched fraction, wherein the liquid methane enriched fraction is recycled into the distillation column,
e) leading the gaseous methane enriched fraction obtained in step d) into the turboexpander so as to expand and thereby cool the methane enriched fraction and
f) leading the expanded and cooled methane enriched fraction obtained in step e) as cooling agent into and through the condenser and withdrawing the methane enriched fraction from the condenser.

[0036] In accordance with a further preferred embodiment of the present, the method further comprises the steps of leading the feed composition into and through the heat exchanger being arranged upstream of the distillation column and of further leading the methane enriched fraction withdrawn from the condenser in step vi) into and through the heat exchanger being arranged upstream of the distillation column so as to cool the feed composition by using the methane enriched fraction withdrawn from the condenser in step vi) as cooling agent. Afterwards, the cooled feed composition is fed into the distillation column.

[0037] In a further development of the idea of the present invention, it is proposed that the method comprises one or more cooling steps for cooling the feed composition by one or more coolers. Preferably, the method comprises a first cooling step of cooling the feed composition in a first cooler, which is preferably an air cooler, and a second cooling step of cooling the feed composition in a second cooler, which is arranged downstream of the first cooler and which is preferably a water cooler, before the cooled feed composition is fed into the distillation column or, if the aforementioned heat exchange step is performed, into the aforementioned heat exchanger.

[0038] Preferably, the feed composition is subjected to a heat exchange in the reboiler. More specifically, the feed composition is led into and through the reboiler being arranged in the recirculation line so as to cool the feed composition by heat exchange with the bottom fraction of the distillation column being recirculated in the recirculation line. The so treated feed composition is then fed into the distillation column or, if the aforementioned heat exchange step with the expanded methane enriched fraction is performed, into the respective heat exchanger, or if the aforementioned one or more cooling steps are performed, into the most upstream of the one or more coolers.

[0039] It is further preferred that the method comprises the steps of gas-liquid-separating the feed composition and to compress the gaseous portion of the feed composition obtained in the gas-liquid-separating step. The compressed gaseous feed composition is then fed into the distillation column or, if the aforementioned heat exchange step with the expanded methane enriched fraction is performed, into the respective heat exchanger, or if the aforementioned one or more cooling steps are performed, into the most upstream of the one or more coolers, or, if the aforementioned heat exchange step with the recirculated bottom fraction of the distillation column is performed, into the reboiler.

[0040] Moreover, the feed stream may be pretreated, for instance by subjecting it to a molecular sieve or by drying it, before the pretreated feed composition is led into any of the aforementioned steps.

[0041] Preferably, the feed composition is fuel gas, from which liquified petroleum gas is separated as the methane depleted fraction.

[0042] Good results are in particular obtained, when the feed composition comprises, based on 100% by weight of the feed composition:

i) 0.1 to 60% by weight of methane,
ii) 10 to 60% by weight of C_2-hydrocarbons,
iii) 0 to 50% by weight of C_3-hydrocarbons,
iv) 0 to 20% by weight of C_4-hydrocarbons,
v) 0 to 40% by weight of C_{5+}-hydrocarbons, and
vi) up 10% by weight of non-hydrocarbons, such a hydrogen, nitrogen, carbon monoxide and/or carbon dioxide.

[0043] A specific example of suitable feed compositions is, based on 100% by weight of the feed composition:

- 24% by weight of methane,
- 33% by weight of C_2-hydrocarbons,
- 21 % by weight of C_3-hydrocarbons,
- 5% by weight of C_4-hydrocarbons,
- 15% by weight of C_{5+}-hydrocarbons, and
- 2% by weight of non-hydrocarbons, such a hydrogen, nitrogen, carbon monoxide and/or carbon dioxide.

[0044] A specific example of a product composition is, based on 100% by weight of the respective product composition:

- 0.26% by weight of methane,
- 25.4% by weight of C_2-hydrocarbons,
- 37.4% by weight of C_3-hydrocarbons,
- 7.8% by weight of C_4-hydrocarbons,
- 29.1% by weight of C_{5+}-hydrocarbons, and
- remainder to 100% by weight of non-hydrocarbons, such a hydrogen, nitrogen, carbon monoxide and/or carbon dioxide.

[0045] A specific example of a methane enriched fraction is, based on 100% by weight of the respective methane enriched fraction:

- 55% by weight of methane,
- 42% by weight of C_2-hydrocarbons and
- 3% by weight of non-hydrocarbons, such a hydrogen, nitrogen, carbon monoxide and/or carbon dioxide.

[0046] In a further development of the idea of the present invention, it is proposed that the distillation is performed as cryogenic distillation. Preferably, the temperature of the mixture within the gas-liquid separator is between -20 to -60°C and preferably between -30 to -50°C, such as -40°C, and/or the temperature of the mixture within the second gas-liquid separator, if present, is between -60 to -100°C and preferably between -70 to -90°C, such as -80°C. The temperature at the bottom of the distillation column is preferably between 55 and 105°C and preferably between 65 and 85°C. Moreover, it is preferred that the pressure within the distillation column is 14 to 69 bar and preferably 20 to 35 bar.

[0047] It is further preferred that the distillation column comprises at least one internal element selected from the group consisting of trays, structured packings, random packings and arbitrary combinations of two or more of the aforementioned elements, wherein the distillation column is operated so that it has a height to accommodate 15 to 40 theoretical stages and preferably 20 to 30 theoretical stages.

[0048] Preferably, a pre-condenser being part of a single-stage vapor compression refrigeration unit is used, in which propylene, propane or ammonia is used as cooling agent.

[0049] Moreover, it is preferred that the methane rich fraction is expanded in the turboexpander by at least the factor 3 to 1, preferably 5 to 1 and more preferably 10 to 1.

[0050] Subsequently, the present invention is explained in more detail with reference to the drawing, which is merely illustrative for an embodiment of the present invention and not at all limiting.

Fig. 1 schematically shows a plant for separating liquified petroleum gas from fuel gas in accordance with one embodiment of the present invention.

Fig. 2 shows a more detailed schematic view of the pre-condensor of the plant shown in fig. 1.

Fig. 3 schematically shows a plant for separating liquified petroleum gas from fuel gas in accordance with another embodiment of the present invention.

[0051] The plant 10 shown in figure 1 comprises a feed inlet line 12^{i}, 12^{ii}, 12^{iii}, 12^{iv}, 12^{v}, 12^{vi}, 12^{vii}, 12^{viii}, which is connected, from the upstream direction to the downstream direction, with a dryer 14, with a gas-liquid separator 16, with a compressor 18, with a reboiler 20, with a first cooler 22 being an air-cooler, with a second cooler 23 being a water cooler, with a heat exchanger 24 and with a distillation column 25. The gas-liquid separator 16 comprises a liquid outlet line 26 and an outlet for gas, which is connected with the feed line section 12^{iii}. Moreover, the reboiler 20 is connected with a recirculation line 28, 28^{i}, the first section 28 of which connecting the bottom of the distillation column 25 with the reboiler and the second portion 28’ of which connecting the reboiler with a side section of the distillation column 25. The reboiler 20 is a tube and shell reboiler 20 and the recirculation line sections 28, 28^{i} are connected with the tubes of the reboiler 20, whereas the feed line sections 12^{iv}, 12^{v} are connected with the shell of the reboiler 20. In addition, the heat exchanger 24 is a tube and shell heat exchanger 24 and the feed line sections 12^{vii}, 12^{viii} are connected with the tubes of the heat exchanger 24.

[0052] The distillation column 25 comprises an overheads outlet line 30 for the methane enriched fraction obtained in the distillation column 25 as overheads fraction and a bottom outlet line 32 for the methane depleted fraction or product composition, respectively, which is obtained in the distillation column 25 as bottom fraction. The overheads outlet line 30 is connected with a pre-condensor 34 being part of a single-stage vapor compression refrigeration unit 35, wherein the pre-condensor 34 is connected via line 36 with the condenser 38. The condenser 38 is a tube and shell condenser, wherein the line 36 leading the methane enriched fraction into the condenser 38 is connected with the shell of the condenser 38. Alternatively, a brazed aluminum heat exchanger as well as cold box may be used in place of a shell and tube exchanger, which are more energy efficient, but involve higher costs. The condenser 38 is also connected with a line 40 being connected with the shell of the condenser 38 for withdrawing the methane enriched fraction from the condenser 38. The line 40 is connected with the gas-liquid separator 42, which comprises an outlet line for gas 44 and an outlet line for liquid 46. While the outlet line for liquid 46 is connected with the distillation column 25 and is in fact a reflux line, the outlet line for gas 44 of the condenser 38 is connected with the turboexpander 48. The turboexpander 48 comprises an outlet line 50 for expanded gas, which is connected with the condenser 38 so as to cool the methane enriched fraction within the condenser 38. The condenser 38 further comprises an outlet line 52 for withdrawing the expanded gas from the condenser 38, which is connected with the heat exchanger 24. Heat exchanger 24 further comprises an outlet line 54 for the methane enriched fraction.

[0053] As shown in more detail in figure 2, the single-stage vapor compression refrigeration unit 35 comprises a first heat exchanger being the pre-condensor 34, a second heat exchanger 62, a throttle 64 and a compressor 66. The first heat exchanger or pre-condensor 34, respectively, is connected via a vapor line 68 for the cooling agent with the compressor 66, which in turn is connected via a vapor line 70 for compressed cooling agent with the second heat exchanger 62. The second heat exchanger 62 further comprises a liquid outlet line 72 for the condensed cooling agent, which is connected with the throttle 64, which in turn is connected via a liquid/vapor line 74 with the first heat exchanger or pre-condensor 34, respectively. While the second heat exchanger 62 functions as condenser for the cooling agent, the first heat exchanger or pre-condensor 34, respectively functions as evaporator for the cooling agent and as pre-condensor for the methane enriched fraction. In other words, for the cooling agent, the second heat exchanger 62, which is hotter and releases heat preferably by cooling it with air and/or water, is a condenser and the first heat exchanger or pre-condensor 34, respectively, which is colder and accepts heat, is an evaporator. At the start of the thermodynamic cycle the cooling agent enters the compressor 66 as a low pressure and low temperature vapor. Then, the pressure of the vapor is increased and the cooling agent 66 leaves the compressor as a higher temperature and higher pressure superheated gas. This hot pressurized gas of the cooling agent then passes through the second heat exchanger 62, where it releases heat to the surroundings as it cools and condenses completely. The cooler high-pressure liquid of the cooling agent then passes through the throttle 64, which is in fact an expansion valve, which reduces the pressure of the cooling agent abruptly and thereby causes that the temperature of the cooling agent drops drastically. The cold low-pressure mixture of liquid and vapor of the cooling agent then travels through the first heat exchanger or pre-condensor 34, respectively, or evaporator, respectively, where the cooling agent vaporizes completely as it accepts heat from the surroundings before it returns to the compressor as a low pressure low temperature gas to start the cycle again. The methane enriched fraction is cooled and thereby partially condensed in the pre-condensor 34 by the cold low-pressure mixture of liquid and vapor of the cooling agent traveling therethrough.

[0054] During the operation of the plant 10, the feed composition is dried in the dryer, before the dried feed composition is subjected in the gas-liquid separator to a gas-liquid separation. While the liquid fraction of the feed composition is withdrawn from the plant, the gas fraction of the feed composition is compressed in the compressor 18 and then cooled in the reboiler 20, in the first cooler 22, in the second cooler 23 and in the heat exchanger 24, before the cold feed composition is fed into the distillation column. During the distillation, a bottom fraction of methane depleted fraction, which is the product composition or liquefied petroleum gas, respectively, is withdrawn via the bottom outlet line 32 from the distillation column 25 and from the plant 10. Furthermore, as overheads fraction a methane enriched fraction is withdrawn from the distillation column via the overheads outlet line 30 and is cooled and partially condensed in the pre-condensor 34 and in the condenser 38, before the so treated methane enriched fraction is separated in the gas-liquid separator 42 into a liquid methane enriched fraction and into a gaseous methane enriched fraction. While the liquid methane enriched fraction is withdrawn from the gas-liquid separator 42 the outlet line 46 and refluxed into the distillation column, the gaseous methane enriched fraction is expanded and thereby cooled in the turboexpander 48. The expanded and cooled methane enriched fraction is led as cooling agent through the condensor as well as through the heat exchanger 28, before the methane enriched fraction is withdrawn via the outlet line 54 from the plant 10.

[0055] The plant 10 shown in figure 3 corresponds to that of figure 1, except that the outlet line 50 of the turboexpander 48 does not directly lead into the condenser 38, but is first led to a second gas-liquid separator 56 being arranged downstream of the distillation column 25, in which the expanded and cooled methane enriched fraction generated in the turboexpander 48 is separated into a liquid fraction and into a gaseous fraction. While the liquid fraction is withdrawn from the second gas-liquid separator 56 via the outlet line 58 and refluxed into the distillation column, the gaseous fraction is led as cooling agent via line 60 into the condenser 38 and via line 52 into the heat exchanger 24, before the methane enriched fraction is withdrawn from the plant via the outlet line 54.

Reference Numeral List

[0056]

10	Plant
12^{i}, 12^{ii}, 12^{iii}, 12^{iv}, 12^{v}, 12^{vi}, 12^{vii}, 12^{viii}	Feed line
14	Dryer
16	Gas-liquid separator upstream of the distillation column
18	Compressor
20	Reboiler
22	First cooler
23	Second cooler
24	Heat exchanger
25	Distillation column
26	Liquid outlet line
28, 28'	Recirculation line
30	Overheads outlet line
32	Bottom-/product composition outlet line
34	Pre-condensor
35	Single-stage vapor compression refrigeration unit
36	Line
38	Condenser
40	Line
42	Gas-liquid separator downstream of the distillation column
44	Outlet line for gas of the condenser
46	Outlet line for liquid of the condenser/reflux line
48	Turboexpander
50	Outlet line of the turboexpander
52	Outlet line of the condenser for withdrawing expanded gas
54	Outlet line for methane enriched fraction
56	Second gas-liquid separator downstream of the distillation column
58	Outlet line for liquid of the second gas-liquid separator/reflux line
60	Line
62	Second heat exchanger of the single-stage vapor compression refrigeration unit
64	Throttle of the single-stage vapor compression refrigeration unit
66	Compressor of the single-stage vapor compression refrigeration unit
68	Vapor line of the single-stage vapor compression refrigeration unit

70	Vapor line of the single-stage vapor compression refrigeration unit
72	Liquid outlet line of the single-stage vapor compression refrigeration unit
74	Liquid/vapor line of the single-stage vapor compression refrigeration unit

Claims

1. A plant (10) for separating a feed composition comprising methane and C_{2+}-hydrocarbons into a methane depleted fraction as product composition and into a methane enriched fraction, wherein the plant (10) comprises:

   a) a distillation column (25) comprising an inlet line, an overheads outlet line (30) for the methane enriched fraction and a bottom outlet line (32) for the methane depleted fraction,
   b) a condenser (38) for condensing a portion of the methane enriched fraction so as to produce a mixed-phase effluent comprising a condensed phase and a vapor phase, wherein the condenser (38) is directly or indirectly connected with the overheads outlet line (30) of the distillation column (25),
   c) a gas-liquid separator (42) for the partially condensed methane enriched fraction being connected with the condenser (38), wherein the gas-liquid separator (42) comprises an outlet line for gas (44) and an outlet line for liquid (46), wherein the outlet line for liquid (46) is connected with the distillation column (25), and
   d) a turboexpander (48) being connected with the outlet line for gas (44) of the gas-liquid separator (42) and comprising an outlet line for expanded gas (50), wherein the outlet line for expanded gas (50) is directly or indirectly connected with the condenser (38) so as to cool the methane enriched fraction within the condenser (38) using the expanded gas as cooling agent, wherein the condenser (38) further comprises an outlet line (52) for withdrawing the expanded gas from the condenser (38).

2. The plant (10) in accordance with claim 1, wherein a pre-condenser (34) for condensing a portion of the methane enriched fraction is arranged between the overheads outlet line (30) of the distillation column (25) and the condenser (38), wherein the pre-condenser (34) is connected with the overheads outlet line (30) of the distillation column (25) and the condenser (38) is connected with the pre-condenser (34).

3. The plant (10) in accordance with claim 2, wherein the pre-condenser (34) is part of a single-stage vapor compression refrigeration unit (35), wherein the single-stage vapor compression refrigeration unit (35) comprises i) two heat exchangers (34, 62), ii) a throttle (64) or an expander and iii) a compressor (66), wherein preferably a first of the two heat exchangers (34) is connected via a vapor line (68) for the cooling agent with the compressor (66), which in turn is connected via a vapor line (70) for compressed cooling agent with the second heat exchanger (62) functioning as condenser for the cooling agent, wherein the second heat exchanger (62) further comprises a liquid outlet line (72) for the condensed cooling agent, which is connected with the throttle (64) or expander, which in turn is connected via a liquid/vapor line (74) with the first heat exchanger (34) functioning as evaporator for the cooling agent and as pre-condensor (34) for the methane enriched fraction.

4. The plant (10) in accordance with any of the preceding claims, wherein the distillation column (25) does not comprise within the distillation column (25) a cooler and does not comprise within the distillation column (25) a condenser (38).

5. The plant (10) in accordance with any of the preceding claims, wherein the outlet line (50) for expanded gas of the turboexpander (48) is directly connected with the condenser (38) so as to cool the methane enriched fraction within the condenser (38) using the expanded gas as cooling agent.

6. The plant (10) in accordance with any of claims 1 to 4, wherein the outlet line (50) for expanded gas of the turboexpander (48) is indirectly connected with the condenser (38) so as to cool the methane enriched fraction within the condenser (38), wherein the outlet line for expanded gas (50) of the turboexpander (48) is connected with a second gas-liquid separator (56), wherein the second gas-liquid separator (56) comprises an outlet line for gas (60) and an outlet line for liquid (58), wherein the outlet line for liquid (58) is connected directly or indirectly with the distillation column (25), and wherein the outlet line for gas (60) is connected with the condenser (38) so as to cool the methane enriched fraction within the condenser (38) using the gas as cooling agent.

7. The plant (10) in accordance with any of the preceding claims, wherein the plant (10) further comprises a feed line (12^{i}, 12^{ii}, 12^{iii}, 12^{iv}, 12^{v}, 12^{vi}, 12^{vii}, 12^{viii}), wherein the feed line (12^{i}, 12^{ii}, 12^{iii}, 12^{iv}, 12^{v}, 12^{vi}, 12^{vii}, 12^{viii}) is connected with a heat exchanger (24) for cooling the feed, which comprises an inlet line for the feed composition (12^{Vii}), an inlet line being connected with the outlet line (52) for withdrawing the expanded gas from the condenser (38)

functioning as cooling agent in the heat exchanger (24), an outlet line (54) for the cooling agent and an outlet line for the cooled feed (12^{viii}), wherein the outlet line for the cooled feed (12^{viii}) is connected with the inlet line (12^{viii}) of the distillation column (25).

8. The plant (10) in accordance with claim 7, wherein the feed line (12^{i}, 12^{ii}, 12^{iii}, 12^{iv}, 12^{v}, 12^{vi}, 12^{vii}, 12^{viii}) is further connected with a first cooler (22) being arranged upstream of the heat exchanger (24), wherein the first cooler (22) is an air cooler, wherein the feed line (12^{i}, 12^{ii}, 12^{iii}, 12^{iv}, 12^{v}, 12^{vi}, 12^{vii}, 12^{viii}) is preferably further connected with a second cooler (23) being arranged downstream of the first cooler (22) and upstream of the heat exchanger (24), wherein the second cooler (23) is a water cooler.

9. The plant (10) in accordance with claim 8, wherein the distillation column (25) comprises a recirculation line (28, 28') and the plant (10) further comprises a reboiler (20), wherein the recirculation line (28, 28') is connected with the reboiler (20) and leads from the bottom of the distillation column (25) to a side section of the distillation column (25), wherein the reboiler (20) is further connected with the feed line (12^{iv}) and comprises an outlet line (12^{v}) for the feed composition, which is directly or indirectly connected with the heat exchanger (24) or, if at least one cooler (22, 23) is present upstream of the distillation column (25), with the most upstream (22) thereof.

10. The plant (10) in accordance with claim 8 or 9, wherein the feed line (12', 12^{ii}, 12^{iii}, 12^{iv}, 12^{v}, 12^{vi}, 12^{vii}, 12^{viii}) is further connected with a gas-liquid separator (16), which comprises an inlet line (12") for the feed composition, an outlet line (26) for liquid and an outlet line for gas (12^{iii}), wherein the outlet line for gas (12^{iii}) is connected with a compressor (18) for compressing the feed composition, wherein the compressor (18) comprises an outlet line (12^{iv}), which is directly or indirectly connected with the heat exchanger (24) or, if at least one cooler (22, 23) and/or a reboiler (20) is present upstream of the distillation column (25), with the most upstream (20) thereof.

11. A method for separating a feed composition comprising methane and C_2+-hydrocarbons into a methane depleted fraction as product composition and into a methane enriched fraction, wherein the method is performed in a plant (10) in accordance with any of the preceding claims.

12. The method in accordance with claim 11, wherein the feed composition is fuel gas, from which liquified petroleum gas is separated as the methane depleted fraction.

13. The method in accordance with claim 11 or 12, wherein the distillation (25) is performed as cryogenic distillation (25), wherein the temperature within the gas-liquid separator (42) is between -20 to -60°C and/or, wherein the temperature within the second gas-liquid separator (56), if present, is between -60 to -100°C.

14. The method in accordance with any of claims 11 to 13, wherein a pre-condenser (34) being part of a single-stage vapor compression refrigeration unit is used, in which propylene, propane or ammonia is used as cooling agent.

15. The method in accordance with any of claims 11 to 14, wherein the methane rich fraction is expanded in the turboexpander (48) by at least the factor 3 to 1, preferably 5 to 1 and more preferably 10 to 1.

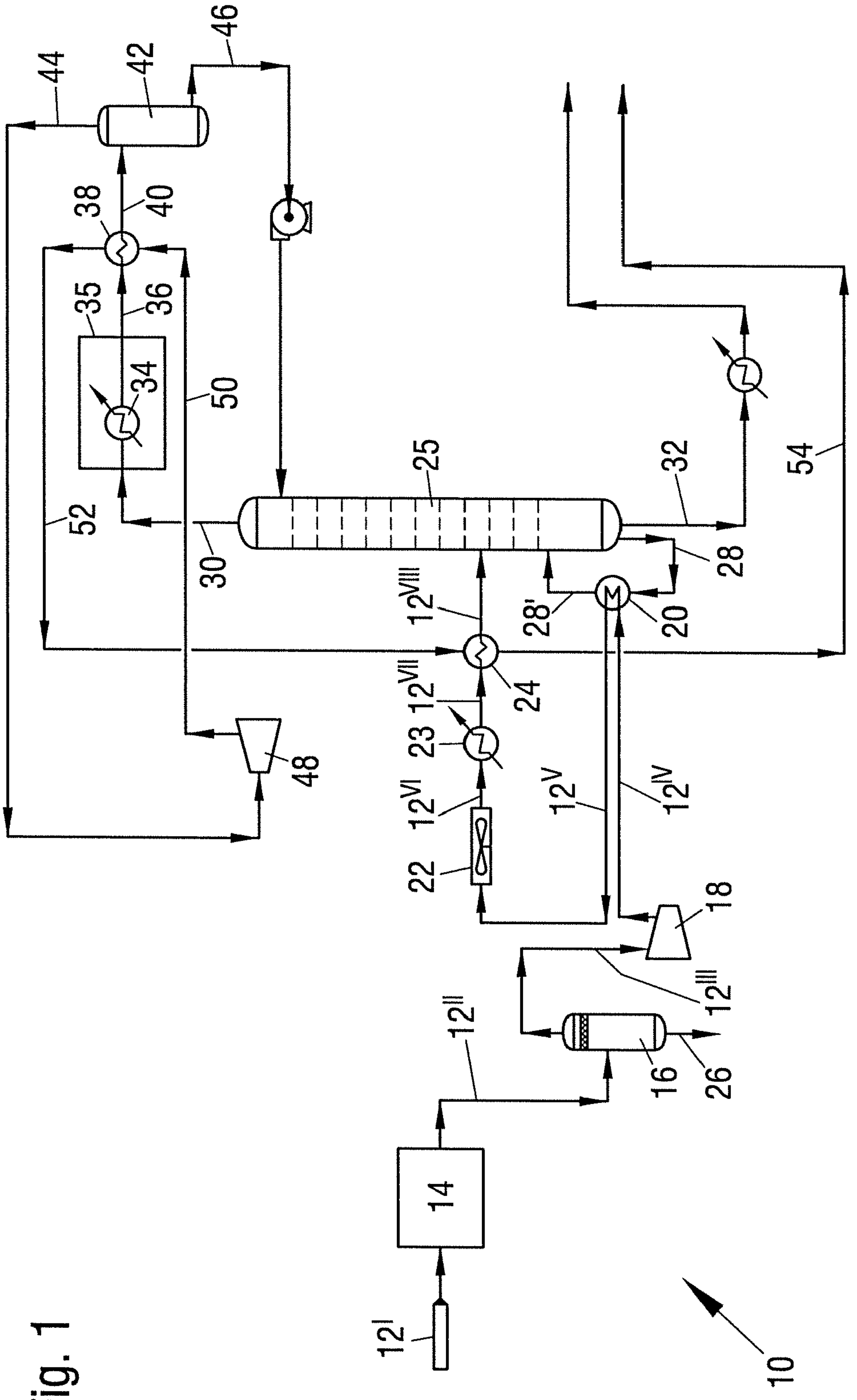

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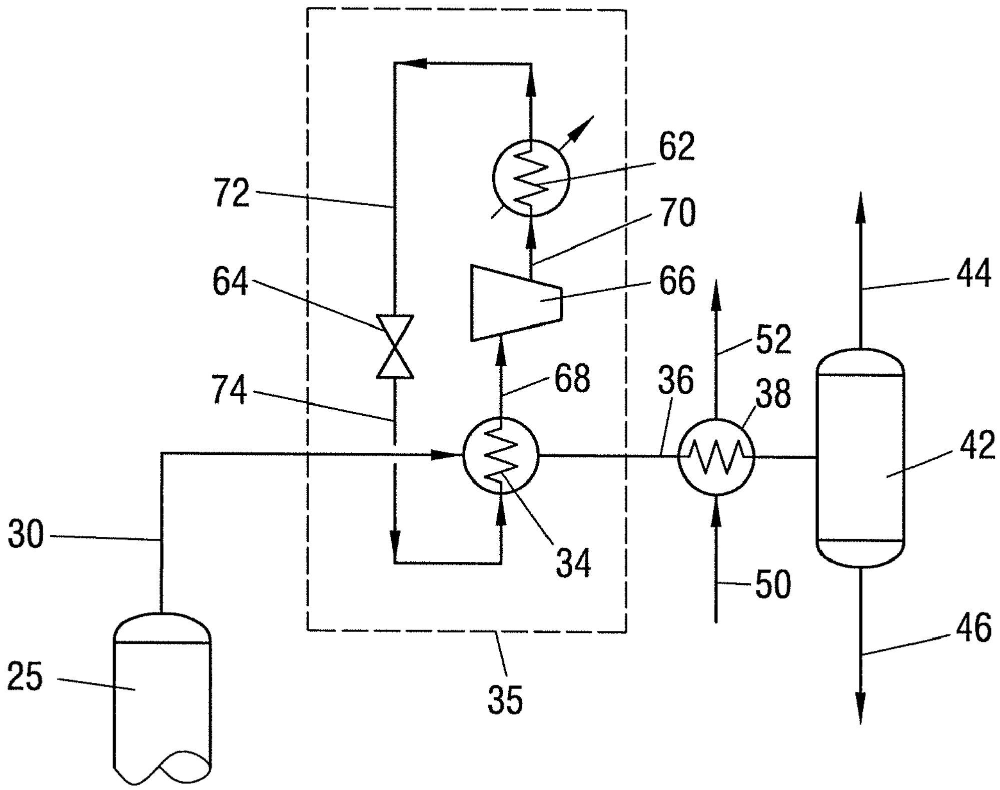
Fig. 1

Fig. 2



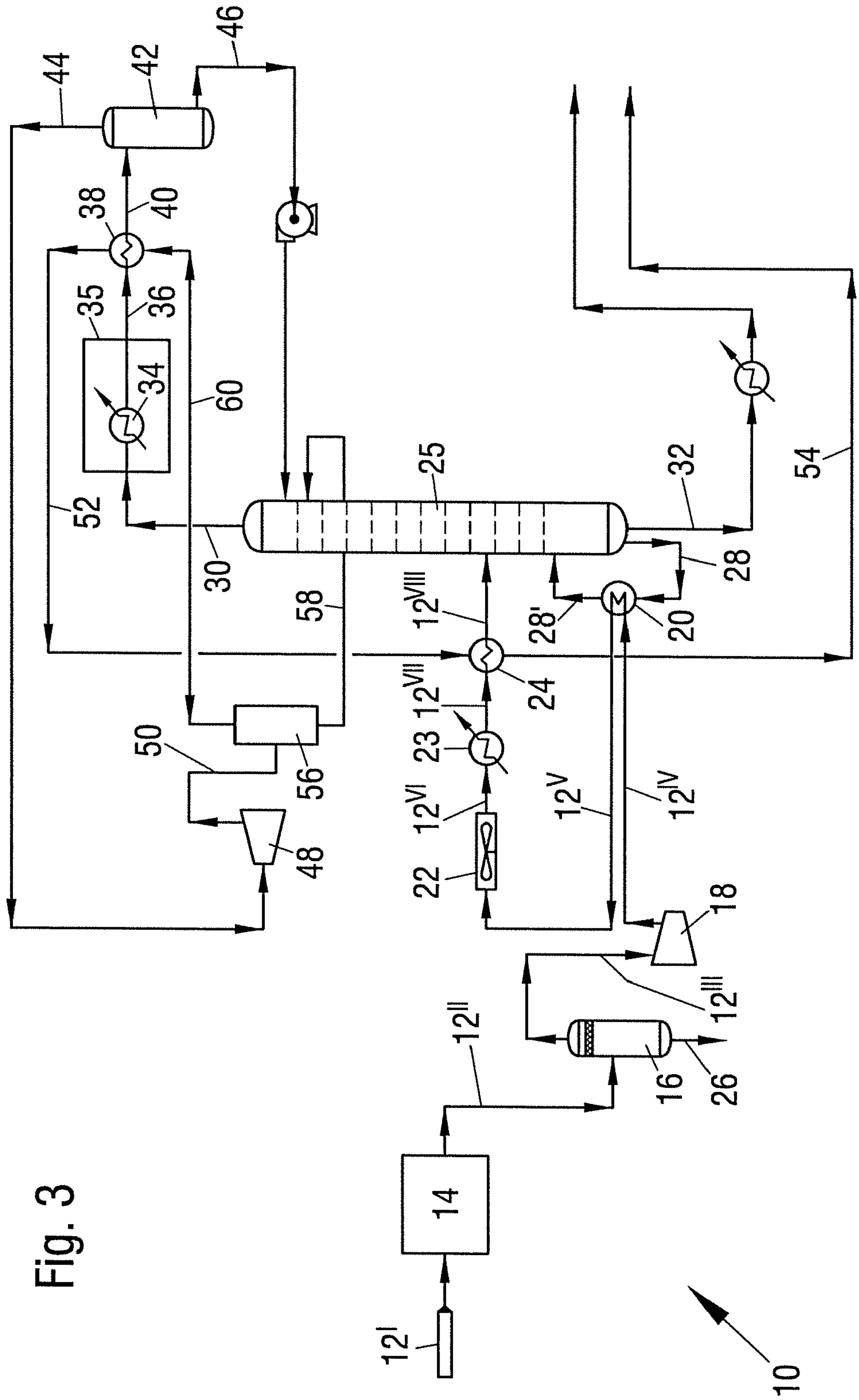

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Fig. 3

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EUROPEAN SEARCH REPORT

Application Number
EP 22 19 8757

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	DE 10 2019 115407 A1 (LINDE GMBH [DE]) 10 December 2020 (2020-12-10)	1,4,5,7, 8,11-13, 15	INV. F25J3/02
Y	* figure 2 *	1-4,6-15	

X	DE 10 2019 115388 A1 (LINDE GMBH [DE]) 10 December 2020 (2020-12-10)	1,4,5, 7-9, 11-13,15	
Y	* paragraphs [0038], [0039], [0055], [0056]; figure 4 *	1-4,6-15	

X	US 4 163 652 A (GAZZI LUIGI [IT] ET AL) 7 August 1979 (1979-08-07)	1,2,4,5, 7,10-13, 15	
Y	* column 2, line 51 - column 3, line 8; figure 6 *	2,3, 8-10,14, 15	

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Y	* figure 1 *	2,3,8, 10,14,15	TECHNICAL FIELDS SEARCHED (IPC)
A		9	F25J

Y	US 2020/032677 A1 (NOURELDIN MAHMOUD BAHY MAHMOUD [SA] ET AL) 30 January 2020 (2020-01-30) * figure 1B *	3,14	

Y	CN 106 839 650 A (SICHUAN HUAYI PETROLEUM NATURAL GAS ENG CO LTD) 13 June 2017 (2017-06-13) * figure 1 *	8-10	

	-/--		

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	21 April 2023	Göritz, Dirk

3

CATEGORY OF CITED DOCUMENTS

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

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
....
& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

page 1 of 2

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EUROPEAN SEARCH REPORT

Application Number
EP 22 19 8757

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	US 5 960 644 A (NAGELVOORT ROBERT KLEIN [NL] ET AL) 5 October 1999 (1999-10-05) * column 6, lines 19-22; figure 1 * -----	1,4,6,7, 11-13 2,3, 8-10,14, 15	
Y	US 2018/274854 A1 (GARBOUCHIAN BERJ [US] ET AL) 27 September 2018 (2018-09-27) * paragraphs [0017] - [0020]; figures * -----	1-4,6-15	
			TECHNICAL FIELDS SEARCHED (IPC)

The present search report has been drawn up for all claims

3

Place of search	Date of completion of the search	Examiner
Munich	21 April 2023	Göritz, Dirk

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EPO FORM 1503 03.82 (P04C01)

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Application Number
EP 22 19 8757

CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing claims for which payment was due.

- [ ] Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due and for those claims for which claims fees have been paid, namely claim(s):

- [ ] No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

- [X] All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

- [ ] As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

- [ ] Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

- [ ] None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

- [ ] The present supplementary European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims (Rule 164 (1) EPC).

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LACK OF UNITY OF INVENTION SHEET B

Application Number
EP 22 19 8757

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. claims: 5(completely); 1-4, 7-15(partially)

being connected with the condenser, wherein the gas-liquid separator comprises an outlet line for gas and an outlet line for liquid, wherein the outlet line for liquid is connected with the distillation column, and
d) a turboexpander being connected with the outlet line for gas of the gas-liquid separator and comprising an outlet line for expanded gas, wherein the outlet line for expanded gas is directly or indirectly connected with the condenser so as to cool the methane enriched fraction within the condenser using the expanded gas as cooling agent, wherein the condenser further comprises an outlet line for withdrawing the expanded gas from the condenser,
wherein the outlet line for expanded gas of the turboexpander is directly connected with the condenser so as to cool the methane enriched fraction within the condenser using the expanded gas as cooling agent.

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2. claims: 6(completely); 1-4, 7-15(partially)

A plant for separating a feed composition comprising methane and C2+-hydrocarbons into a methane depleted fraction as product composition and into a methane enriched fraction, wherein the plant comprises:
a) a distillation column comprising an inlet line, an overheads outlet line for the methane enriched fraction and a bottom outlet line for the methane depleted fraction,
b) a condenser for condensing a portion of the methane enriched fraction so as to produce a mixed-phase effluent comprising a condensed phase and a vapor phase, wherein the condenser is directly or indirectly connected with the overheads outlet line of the distillation column,
c) a gas-liquid separator for the partially condensed methane enriched fraction being connected with the condenser, wherein the gas-liquid separator comprises an outlet line for gas and an outlet line for liquid, wherein the outlet line for liquid is connected with the distillation column, and
d) a turboexpander being connected with the outlet line for gas of the gas-liquid separator and comprising an outlet line for expanded gas, wherein the outlet line for expanded gas is directly or indirectly connected with the condenser so as to cool the methane enriched fraction within the condenser using the expanded gas as cooling agent, wherein the condenser further comprises an outlet line for withdrawing the expanded gas from the condenser,
wherein the outlet line for expanded gas of the turboexpander is indirectly connected with the condenser so as to cool the methane enriched fraction within the

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LACK OF UNITY OF INVENTION SHEET B

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The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

condenser, wherein the outlet line for expanded gas of the turboexpander is connected with a second gas-liquid separator, wherein the second gas-liquid separator comprises an outlet line for gas and an outlet line for liquid, wherein the outlet line for liquid is connected directly or indirectly with the distillation column, and wherein the outlet line for gas is connected with the condenser so as to cool the methane enriched fraction within the condenser using the gas as cooling agent.

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