METHOD AND SYSTEM FOR PRODUCING LNG.

The present invention relates to a method for optimal production of liquefied natural gas (LNG) on a fixed or floating offshore installation, as can be seen in the ingress of the independent claim 1.

The invention also relates to a system for carrying out the method comprising a fractionation column for feeding in of a feed gas, a heat exchanger system for cooling down and partially condensing the overhead gas stream from the fractionation column, a separator to separate the two-phase stream from the heat exchanger system, a device for return of fluid from the separator to the fractionation column and feeding this fluid to the upper part of the column as reflux, and a device for routing the gas from the separator back to the heat exchanger system for further cooling down and liquefaction to LNG.

The invention aims to use a closed gas expansion process to liquefy the natural gas, and in that the gas is first fed through a fractionation column where the gas is cooled and separated into an overhead fraction with reduced content of pentane (C5) and heavier components, and a bottom fraction enriched with the heavier hydrocarbons, furthermore, in that the fractionation column reflux is generated as an integrated part of the system for liquefaction in that the overhead gas is partially condensed. By carrying out the liquefaction in accordance with the invention, production of liquid gas with maximum content of ethane and LPG (liquefied petroleum gas) is achieved at the same time as the efficiency of the gas expansion process is increased and the by-production of unstable/volatile fluid with a high content of ethane, LPG and pentane is minimised.

In particular, the invention comprises a method and a system for liquefaction of natural gas or other hydrocarbon gas from a gas field or from a gas/oil field, where it is appropriate to liquefy the gas to make it possible to transport the gas

from the source to the market. This is particularly relevant for offshore oil/gas fields.

In this context, natural gas means a mixture of hydrocarbons where an essential part consists of methane. Natural gas is normally liquefied by considerably cooling down the gas such that it condenses and becomes a liquid. With LPG is meant liquid petroleum gas that encompasses propane and butanes (C4, C4 components).

The aim of the invention is to render liquefaction of gas energy efficient at the same time as the process is kept simple so that the equipment can be used offshore, and then especially on floating installations. By-production of condensate during the liquefaction is minimised and the efficiency is maximised (the need for fuel gas is minimised).

The method according to the invention is characterised by the following steps:

1) that the feed gas is led through a fractionation column (150) where it is cooled and separated into an overhead fraction with reduced content of pentane (C5) and heavier components, and a bottom fraction enriched with heavier hydrocarbons,

2) that the overhead fraction from the fractionation column is fed into a heat exchanger system (110) and is subjected to partial condensation to form a two-phase fluid, and the two-phase fluid is separated in a suitable separator (160) to a liquid (5) rich in LPG and pentane (C3-C5) which is re-circulated as cold reflux to the fractionation column (150), while the gas (6) containing lower amounts of C5 hydrocarbon and hydrocarbons heavier than C5, is routed for further treatment in the heat exchanger system(110) for liquefaction to LNG with maximum content of ethane and LPG, and

3) that the cooling circuit for liquefaction of gas in the heat exchanger system comprises an open or closed gas expansion process with at least one gas expansion step.

The preferred embodiments of the method are defined in the dependent claims 2-10.

The system according to the invention is characterised in that the cooling system which is used for cooling, condensing and liquefaction of the gas in the heat exchanger system comprises an open or closed gas expansion process with at least one gas expansion step. The system is preferably designed and

configured to separate the feed gas so that the overhead gas stream of the system will be enriched with the majority of the butane (C4) and hydrocarbons with a lower normal boiling point than butane, and the bottom product of the fractionation column will be enriched with most of C6 and components with a normal boiling point higher than C6.

A first aspect provides a method for production of liquefied natural gas from an incoming feed gas (1), characterised by the following steps: a) the incoming feed gas is led through a fractionation column (150) where it is cooled and separated into a first overhead gas stream (2), with a reduced content of a first group of hydrocarbons that have a molecular weight higher than pentanes (C5) and enriched with most of the butane (C4) and a second group of hydrocarbons with a lower normal boiling point than butane, and a bottom fraction (3) wherein a third group of hydrocarbons originating from the incoming feed gas, and having a molecular weight from hexanes (C6) and higher is conserved, b) the first overhead gas stream (2) of the fractionation column is led into a heat exchanger system (110) and is subjected to a partial condensation to form a two-phase fluid, and the two-phase fluid is separated in a suitable separator (160) into a fluid (5) rich in liquefied petroleum gas and pentane (C3-C5) which is re-circulated as cold reflux to the fractionation column (150), and a second overhead gas stream (6), enriched with most of the butane (C4) and hydrocarbons with a lower normal boiling point than butane, wherein said overhead gas stream (6) is reintroduced into the heat exchanger system (110) for liquefaction to liquefied natural gas consisting essentially of methane, ethane, propane and butane, and wherein c) the cooling circuit for liquefaction of gas in the heat exchanger system comprises an open or closed gas expansion process with at least one gas expansion step.

A second aspect provides a system for carrying out the method as defined above comprising a fractionation column (150) for feeding in a feed gas, a heat exchanger system (110) for cooling down and partially condensing a first overhead gas stream of the fractionation column, a separator (160) to separate the partially condensed first overhead gas stream, set up to recycle fluid from the separator to the fractionation column and import this fluid to the upper part of the column as a reflux, and appliance to lead a

second overhead gas stream form the separator back to the heat exchanger system for further cooling down and liquefaction to liquefied natural gas, characterised in that the cooling system which is used for cooling down, condensing and liquefying of gas in the heat exchanger system comprises an open or closed gas expansion process with at least one gas expansion step.

A third aspect provides an optimized gas liquefaction system of the gas expansion type for the production of liquefied natural gas from an incoming natural gas stream, characterised in that the system comprises: a) an open or closed gas liquefaction circuit comprising a gaseous refrigerant, at least one gas expander for cooling the refrigerant by gas expansion, and one or more heat exchangers for heat exchange between the natural gas, liquefied natural gas and refrigerant streams, b) a fractionation column arranged for receiving the incoming natural gas stream prior to introduction of the natural gas stream into the liquefaction circuit, said fractionation column being further arranged to cool and separate the incoming natural gas stream into a first overhead gas stream, with a reduced content of the hydrocarbons that have a molecular weight higher than pentanes (C5) and enriched with most of the butane (C4) and hydrocarbons with a lower normal boiling than butane, and a bottom liquid fraction wherein hydrocarbons having a molecular weight equivalent to or higher than the molecular weight of hexanes (C6) are conserved, and arranged to lead the first overhead gaseous fraction to at least one of the heat exchangers of the liquefaction circuit, whereby the first overhead gas stream is cooled to a two-phase fluid, and c) a separator arranged for receiving the two-phase fluid and separating the two-phase fluid into a second overhead gas stream-wherein hydrocarbons having a molecular weight from butanes and lighter are conserved, and a liquid component rich in liquefied petroleum gas and pentanes (C3-C5), and further arranged to return the liquid component back to the fractionation column as a cold reflux liquid and to return the gas component to the liquefaction circuit for further cooling and condensation to liquefied natural gas.

A fourth aspect provides a system as defined above, wherein the liquefaction circuit comprises the gaseous refrigerant at an inlet pressure of 3 – 10 MPa being fed to the heat

exchanger or system of heat exchangers and cooled to a temperature between 0 and -120 deg C, and further wherein the cooled gaseous refrigerant is expanded to a pressure between 5% and 40% of the inlet pressure, and then being led back to the heat exchanger or system of heat exchangers to provide cooling.

Background:

Liquefaction of natural gas can be carried out with the use of a gas expansion process, where a cooling medium goes through a processing circuit based on compression, cooling, expansion and thereafter heat exchange with the fluid that is to be cooled down. For example, for liquefaction of natural gas, one can use a compressed cooling medium in gas phase, normally nitrogen or methane, which is pre-cooled and thereafter expanded across an expansion valve or a turboexpander. The gas expansion generates very cold gas, or a mixture of gas and liquid, which is then used for liquefaction of natural gas and to pre-cool the compressed cooling medium gas. The gas expansion processes are relatively simple and therefore very well suited to offshore installation. However, the processes have a somewhat lower efficiency than the more advanced processes, such as, for example, mixed refrigerant cycle processes, and thus require much compression equipment and much energy.

In order to produce LNG it is normally required that the gas has a relatively high content of methane. However, most of the feed gases will also contain some heavier hydrocarbons such as ethane, propane, butane, pentane, etc. Some requirements with respect to the content of heavier hydrocarbons in the liquid gas are normally present:

The specific energy content per cubic meter of liquefied gas must normally not exceed given sales specifications.

The content of pentane (C5) and upwards, and also aromatic compounds of the liquid gas, must be kept below defined limits to avoid freeze out in the cooling process.

The simplest way to limit the content of heavier hydrocarbons in the liquid gas is to partially condense the gas and then separate the condensed liquid from the gas, which is further cooled for liquefaction. The separation is normally carried out as an integrated part of the cool down process, typically at a

temperature between 0 ^{o}C and -60 ^{o}C. Separated condensate can be heated up again as a part of the cooling process to utilise the refrigeration potential.

In large land based LNG installations (so called "base load" installations) most of the propane and heavier hydrocarbons are normally removed and in many cases also a considerable part of ethane, before or as a part of, the liquefaction. This is done to meet the sale specifications and to be able to produce and sell the valuable ethane, LPG and condensate/naphtha. Comprehensive processes are normally used with low temperature fractionation columns both as a part of the cool down process and as separate units outside the cooling system.

However, for offshore LNG production it is undesirable to handle products other than the liquid natural gas. Where oil or condensate is also produced one can however permit separation of condensate for stabilisation and export together with another oil and/or condensate. However, stabilised condensate will, in the main, consist of C6+ with a relatively low content of pentane and lighter components. Hydrocarbons lighter than C6 can generally not be stored or transported safely without being cooled down or being under pressure. Some separated hydrocarbons or condensate can be used as fuel, but beyond that it is desirable to retain these components in the LNG product. Due to smaller LNG volumes and the possibility for later blending into large LNG volumes, it can be appropriate offshore to produce a liquid natural gas with a considerably higher, and preferably a maximum, content of heavier hydrocarbons.

The present invention represents a considerable optimisation for application offshore, and especially on a floating unit, in that a relatively simple and robust gas expansion process is used for liquefaction of natural gas, and in that the energy efficiency of this process is increased at the same time as the amount of liquid gas is maximised by maximising the content of ethane and LPG, at the same time as the amount of hydrocarbons heavier than methane which is separated out as bi-products in the liquefaction process is minimised.

An installation which comprises the system according to the invention can thereby simply be adapted and be installed, for example, on board floating offshore installations where space is often a limiting factor.

References to known technology and other publications, and comparisons with the present invention:

Initially reference is made to EP-1.715.267 which describes a method which includes natural gas being cooled and being led through a fractionation column where it is separated into an overhead fraction and a bottom fraction. The bottom fraction is enriched with heavier hydrocarbons and is exported out of the system. The overhead fraction is cooled and forms a two-phase fluid which is separated in a separator. The liquid phase is re-circulated to the fractionation column whilst the gas phase is fed further to a heat exchanger system. Cooling of the overhead fraction is carried out with a free standing cooler. The EP patent consequently describes a classical and well-known distillation process.

Furthermore, the set-up is standard practice in so-called "base load" LNG installations, where both cooler 5 and cooler 11 (ref. figures in the EP patent) are parts of the pre-cooling installation of the plant, which is normally carried out as a multistep propane cooling installation. However, the set up in the EP patent does not integrate a fractionation column and a downstream LNG condensation process as one aims with the present invention. Integration is here meant that two systems are tightly connected together and function as one system and that material streams and/or energy streams are flowing both ways between the systems.

The refrigeration work which according to EP-1.715.267 cools the overhead fraction and generates so-called reflux to the fractionation column, comes according to the description not from the same cooling circuit that carries out further cooling and condensation of the natural gas, but apparently from an external cooling process.

International patent application WO-2005/071333 describes a well-known double gas expansion which is used to liquefy boil off gas from storage tanks for LNG. In practice, such boil off gases contain only methane and nitrogen.

Patent publications US2006/0260355 A1 and US 6,662,589 describe systems which apparently are similar to the present invention, but which in reality are considerably different from the present invention. The systems in the referred publications comprise processes for simultaneous liquefaction of natural gas and recovery / separation of components heavier than methane, i.e. ethane and

heavier components, where ethane, LPG and heavier components are fractionated into sales products and where the liquid gas has a considerably reduced content of ethane and heavier components. This is achieved by leading the feed gas to a fractionation column where it is contacted with an ethane rich reflux such that the fractionation column separates the feed into an overhead gas fraction with a considerably reduced content of components heavier than methane and a liquid stream from the bottom considerably enriched with components heavier than methane. The ethane rich reflux is generated in that the gas from the fractionation column is partially condensed, and isn addition by cooling down and condensing a stream rich in ethane which is re-circulated from a fractionation train for fractionation of the bottom fraction from the fractionation column.

Patent publications US 6,401,486, US 6,742,358 and WO2006/115597 A2 describe systems for simultaneous liquefaction of natural gas and recovery / separation of components heavier than methane, i.e. ethane and heavier components. The processes themselves are also considerably different from and more complex than the present invention in that the feed gas is first cooled down in, amongst others, the heat exchanger(s) for liquefaction of gas, and also by heat exchange with a flash expanded separated liquid and with fluid from the bottom of the column. Furthermore, the whole or part of the feed gas stream is expanded through a turboexpander or a Joule-Thompson expansion valve before it is led to the fractionation column.

The patent publications US 2006/0260355 A1, US patent 6,662,589, US patent 6,401,486 and also US patent 6,742,358 consequently relate to processes to minimise the content of ethane, LPG and also the heavier hydrocarbons in the liquid gas, whilst the present invention comprises a system and a method to maximise the content of methane, ethane and LPG in the liquid gas. None of the US patent application 2006/0260355 A1, US patent 6,662,589, US patent 6,401,486 or US patent 6,742,358 describe the increase in energy efficiency which can be achieved for a gas expansion process with the integrated separation column that receives a reflux rich in C3-C5 from the liquefaction heat exchanger(s) for production of LNG.

A process is described in DE patent 10205366 for simultaneous liquefaction of natural gas and recovery / separation of components heavier than ethane, and where separated LPG and heavier components are fractionated to sales

products. This is achieved by first partially cooling down the feed gas in the condensation installation for liquefaction of natural gas and then by leading the cooled down feed gas to a fractionation column where it comes into contact with a reflux rich in ethane so that the fractionation column separates the feed into an overheard gas fraction with a considerably reduced content of components heavier than ethane, and a liquid stream from the bottom considerably enriched with components heavier than ethane. The reflux rich in ethane is generated in that the gas from the fractionation column is partially condensed and thereafter brought into contact with a C4/C5 stream in a second fractionation column, and where the C4/C5 fraction is re-circulated from a fractionation train for fractionation of the bottom product from the first fractionation column. DE patent 10.205.366 comprises, in other words, a process to minimise the content of LPG of the liquid gas, and also the heavier hydrocarbons, while the present invention comprises a system and a method to maximise the content of LPG in the liquid gas. The publication DE 10.205.366 does not describe an increase in energy efficiency which can be achieved in a gas expansion process with the integrated separation column which receives a reflux rich in C3-C5 from the liquefaction heat exchanger(s) for production of LNG.

In US patent 4,690,702 an LNG process is described where the feed gas is firstly pre-cooled in the cooling installation for LNG production, thereafter to be fed to a first fractionation column where it is brought into contact with a cooled ethane rich reflux that is re-circulated from a second fractionation column for fractionation of the bottom stream from the first column. The publication does not comprise a system where a reflux rich in C3-C5 for a fractionation column is achieved by partially condensing the overhead gas product from the fractionation column as an integrated part of an LNG process.

US patent 7,010,937 shows a system for simultaneous liquefaction of natural gas and recovery / separation of components heavier than methane. According to this publication the gas feed is pre-cooled and partially condensed so that a liquid stream can be separated in a separator and where this liquid stream is fractionated in a first fractionation column to generate an overhead gas which is cooled down to produce a reflux for a second fractionation column. The gas flow from the separator is expanded across a gas expander and fed to the second fractionation column. Therefore this US patent has little in common with the present invention as it is defined in the subsequent claims.

Description of the invention:

The invention will now be described in more detail with reference to the enclosed figures in which:

Figure 1 shows a principal embodiment with main components and main functionality.

Figure 2 shows the invention with an alternative embodiment.

Figure 3 shows the invention with an alternative embodiment that includes further stabilisation of the heavier hydrocarbons that are separated out (condensate).

Figure 4 shows the invention in detail carried out by using a double gas expansion process.

Figure 5 shows the invention carried out by using a hybrid cooling circuit with a gas expansion loop and a liquid expansion loop.

Figure 6 shows an example of a hot temperature curve and a cold temperature curve (composite curve) for a conventional nitrogen expansion cycle.

Figure 7 shows an example of a hot temperature curve and a cold temperature curve (composite curve) for a nitrogen expansion cycle obtained by using the present invention.

Figure 8 shows a comparison of the curves shown in the figures 6 and 7.

With reference to figure 1 the system for optimised liquefaction of gas comprises, as a minimum, the following principle components:

- an incoming gas stream 1 which shall be cooled down and liquefied,
- a fractionation column 150 in which the incoming gas is cooled and is separated into an overhead fraction 2 with a reduced content of pentane and heavier components,
- a bottom fraction 3 enriched with the heavier hydrocarbon components,
- a system of heat exchangers 110, in which the incoming gas is cooled down and partially condensed for separation of heavier hydrocarbons, and further cooling and liquefaction,

- a product stream 11 comprising cooled liquefied gas,
- a product stream 3, which mainly comprises pentane and heavier hydrocarbons, and
- a cooling system for cooling and liquefaction of the gas comprising a gas phase cooling medium stream 20, at least one cycle compressor 100, at least one aftercooler 130, at least one gas expander 120.

Incoming and cleaned feed-gas 1, for example, a methane rich hydrocarbon gas, is first fed to a fractionation column 150, where the gas is cooled down in contact with a colder reflux fluid. During the cooling and counter current contact with the colder fluid, the feed gas is separated into an overhead fraction 2 with a reduced content of the hydrocarbons that have a molecular weight higher than pentane (C5), and a bottom fraction 3 enriched with C6 and hydrocarbons that have a higher molecular weight than C6. The overhead fraction 2 from the fractionation column is then led to the heat exchanger system 110, where the gas is cooled down and partially condensed so that the resulting two-phase fluid 4 can be separated in a suitable separator 160. A liquid 5 rich in LPG and pentane (C3-C5), which is separated in the separator 160, is re-circulated as cold reflux to the fractionation column 150. (Note: Her er det feil i originalteksten (150 / 160) men det bør være opplagt for behandlende instans at dette er skrivefeil og at meningen ikke forandres) As this fluid is generated by condensation by cooling, the reflux liquid 5 will have a lower temperature than the feed gas 1. The gas 6 from the separator 160 has now further reduced its content of C5 hydrocarbons and hydrocarbons higher than C5. This gas is then led back to the heat exchanger system 110 for further cooling, condensation and sub cooling. The liquefied gas 11 is alternatively led through a control valve 140 that controls the operating pressure and flow through the system.

In a preferred embodiment the gas feed stream 1 is pre-cooled by a suitable external cooling medium such as available air, water, seawater or a separate suitable refrigeration system/pre-cooling system. For the latter external cooling method, a separate closed mechanical refrigeration system with propane, ammonia or other appropriate refrigerant is often used.

In a preferred embodiment the fractionation column 150 and the separator 160 are operated at pressures and temperatures such that the complete system (the fractionation column 150 and reflux separator 160) generate a component split/separation point in the normal boiling point area (NBP) between -120°C

and 60C. This can, for example, correspond to the light key component for the separation being butane (C4) with a normal boiling point between -12°C and 0°C, and the heavy key component being a C6 component with a boiling point between 50°C and 70°C. The overhead gas stream 6 of the system will then be enriched with most of the butane (C4) and hydrocarbons with a lower normal boiling point than butane. The bottom product 3 from the fractionation column will be enriched with most of C6 and components with a normal boiling point higher than C6, while pentane (C5, NBP = 28 – 36°C) is a transition component which is distributed in the gas product of the system and the bottom product from the fractionation column.

Cooling and condensation of the feed gas in the heat exchanger system 110 is provided by a closed or open gas expansion process. The cooling process starts in that a cooling medium 21 comprising a gas or a mixture of gases (such as pure nitrogen, methane, a hydrocarbon mixture, or a mixture of nitrogen and hydrocarbons), at a higher pressure, preferably between 3 and 10 MPa, is fed to the heat exchanger system 110 and cooled to a temperature between 0°C and -120°C, but such that the cooling medium stream is mainly a gas at the prevailing pressure and temperature 31. The pre-cooled cooling medium 31 is then led into a gas expander 121 where the gas is expanded to a lower pressure between 5%-40% of the inlet pressure, but preferably to between 10% and 30% of the inlet pressure, and such that the cooling agent mainly is in the gas phase. The gas expander is normally an expansion turbine, also called turboexpander, but other types of expansion equipment for gas can be used, such as a valve. The flow of pre-cooled cooling agent is expanded in the gas expander 121 at a high isentropic efficiency, such that the temperature drops considerably. In certain embodiments of the invention, some liquid can be separated out in this expansion, but this is not a requirement for the process. The cold stream of cooling agent 32 is then led back to the heat exchangers 110 where it is used for cooling and alternatively condensing of the other incoming warm cooling medium streams and the gas that shall be cooled, condensed and sub cooled.

After the cold cooling medium stream 32 has been heated in the heat exchanger system 110, the cooling medium will exist as the gas stream 51, which in a closed loop embodiment is recompressed in an appropriate way for recycle, and is cooled with an external cooling medium, such as air, water, seawater or an appropriate refrigeration unit.

Alternatively, the cooling system in an open embodiment will use a cooling medium 21 consisting of a gas or a mixture of gases at a higher pressure received from an appropriate source, for example, from the feed gas that is to be treated and cooled down. Furthermore, the open embodiment comprises that the low pressure cooling medium stream 51 is used for other purposes or, in an appropriate way, is recompressed to be mixed with the feed gas that is to be treated and cooled down.

In a preferred embodiment, the returning cooling medium stream 51 is led from the heat exchanger 110 to a separate compressor 101 driven by the expansion turbine 121. In this way, the expansion work is utilised, and the energy efficiency of the process is improved. After the compressor 101, the cooling agent is cooled further in a heat exchanger 131, before the stream is further compressed in the cycle compressors 100. The cycle compressors 100 can be one or more units, alternatively one or more stages per unit. The cycle compressor can also be equipped with inter cooling 132 between the compressor stages. The compressed cooling medium 20 is then cooled by heat exchange in an aftercooler 130 with the help of an appropriate external cooling medium, such as air, water, seawater or a suitable separate refrigeration cycle, to be re-used as a compressed cooling medium 21 in a closed loop.

In a preferred embodiment, the system of heat exchangers 110 is one heat exchanger which comprises many different "warm" and "cold" streams in the same unit (a so-called multi-stream heat exchanger).

Figure 2 shows an alternative embodiment where several multi-stream heat exchangers are connected together in such a way that the necessary heat transfer between the cold and warm streams can be accomplised. Figure 2 shows a heat exchanger system 110 comprising several heat exchangers in series. However, the invention is not related to a specific type of heat exchanger or number of exchangers, but can be carried out in several different types of heat exchanger systems that can handle the necessary number of hot and cold process streams.

Figure 3 shows an alternative embodiment where the fractionation column 150 is equipped with a reboiler 135 to further improve the separation (a sharper split between light and heavy components), and also to reduce the volatility of the

bottom fraction in the column. This can be used to directly produce condensate which is stable at ambient temperature and atmospheric pressure.

Figure 4 shows in details the invention applied in a more advanced embodiment where a double gas expansion process is used. In this embodiment, the compressed cooling medium stream 21 is first cooled down to an intermediate temperature. At this temperature, the cooling agent stream is divided into two parts, where one part 31 is taken out of the heat exchanger and is expanded in the gas expander 121 to a low pressure gas stream 32. The other part 41 is pre-cooled further to be expanded in the gas expander 122 to a pressure essentially equal to the pressure in stream 32. The expanded cold cooling agent streams 32, 42 are returned to different inlet locations on the heat exchanger system 110 and are combined to one stream in this exchanger. Heated cooling agent 51 is then returned to recompression. In an alternative embodiment to the system in Figure 3, the compressed cooling agent stream 20 in the double gas expansion circuit can be split into two streams before the heat exchanger 110 to be cooled down to different temperatures in separate flow channels in the heat exchanger 110.

The same applies for the heating of the returned cold cooling agent streams 32, 42. The embodiment is otherwise in accordance with Figure 3.

Figure 5 shows in detail the invention carried out with the use of a hybrid cooling loop where one cooling medium is used both in a pure gas phase and in a pure liquid phase. In this embodiment a closed cooling loop provides the cooling of the feed gas in the heat exchanger system 110. The Said cooling cycle starts by methane or a mixture of methane and nitrogen, where methane makes up at least 50 % of the volume, being compressed and aftercooled to a compressed cooling medium stream 21, and where this cooling medium stream is pre-cooled, and at least a part 31 of the cooling medium stream is used in the gas phase in that it is expanded across a gas expander 121 and that at least a part 41 of the cooling agent stream is condensed to liquid and is expanded across a valve or liquid expander 141.

It is emphasised that the embodiment of the invention is not limited to the cooling processes described above only, but can be used with any gas expansion cooling process for liquefaction of natural gas or other hydrocarbon

gas, where the cooling is mainly achieved by using one or more expanding gas streams.

By carrying out the liquefaction of the natural gas in accordance with the invention, a product of liquefied gas is produced which has a maximum content of methane, ethane and LPG, however, at the same time does not contain more than the permitted level of pentane and heavier hydrocarbons with a normal boiling point above 50 – 60^{0}C. At the same time, the by-production of volatile hydrocarbons with considerable content of ethane, propane and butane is minimised or eliminated, where such will be difficult to handle on an offshore installation for LNG production. At the same time more liquid natural gas will also be produced with lower energy consumption than for similar cooling cycles configured without the fractionation column which receives cold and LPG-rich reflux from the cooling down process. (Note: Her er det skrivefeil i originaltekst)

The reason for the energy consumption for the gas expansion processes for liquefaction of the natural gas is being reduced with the use of the invention compared to a similar cooling process without the integrated separation column has several aspects:

The heavier hydrocarbons which are essential to separate out to prevent freezing during the liquefaction will be condensed and be separated at considerably higher temperatures than in conventional methods, in that much of the condensing takes place in the fractionation column. This reduces the exergy loss in the cooling process in that cooling load is moved to a higher temperature range.

The heat exchanger system 100 of the cooling process receives the gas which is to be liquefied as stream 2 (the overhead gas stream in the fractionation column), which has a reduced temperature with respect to the actual gas feed stream 1. A gas expansion process is characterised in that the warm and cold cooling curves are dominated by the large amount of gas which is used as cooling medium. These gas streams form linear cooling curves. The reduced feed temperature into the heat exchanger results in a "break point" on the warm cooling curve (the sum of the streams which are being cooled), so that it is possible to obtain a general reduction of the distance between the warm and cold cooling curves. This provides a better temperature adaption, reduced

exergy loss and thus a reduced energy consumption to drive the cooling process.

Preliminary analyses and comparisons show that necessary compressor work per kg liquid natural gas which is produced can be reduced by 5 – 15 % for a gas expansion cycle carried out in accordance with the invention compared to conventional methods.

Figure 6 shows warm and cold cooling curves (warm and cold composite curves, i.e. the sum of all warm streams that are to be cooled down and the sum of all cold streams that are to be heated up, respectively) for the heat exchanger system 110 carried out in accordance with the present invention, and with a double nitrogen expansion process as cooling system. Figure 7 shows corresponding warm and cold cooling curves for a corresponding cooling process with the same feed, but carried out in a conventional way without the fractionation column. The curves appear to look alike, but by considering Figure 8, which shows a section and both the systems in (Note: skrivefeil i originaltekst) the same curve, the "break point" and the better adaption can clearly be seen.

Example

The example below shows natural gas with 90.4 % methane by volume which is to be liquefied, where the invention is used to maximise the amount of liquid gas and at the same time minimise the by-production of unstable hydrocarbon liquid with a high content of ethane, propane and butane. The stream data refer to Figures 1, 2, 3, 4 or 5.

Stream No.	1	2	3	4	5	6	11
Gas fraction	1.00	1.00	0.00	0.95	0.00	1.00	0.00
Temperature (^{0}C)	40.0	19.2	35.9	-20.0	-20.0	-20.0	-155.0
Pressure (kPa abs)	2740	2738	2745	2725	2730	2723	2655
Mole flow (kmol/h)	4232	4422	44	4422	235	4185	4185
Mass flow (kg/h)	78980	87539	3410	87539	11969	75541	75541
Mole fraction (%)							
Nitrogen	0.51 %	0.49 %	0.02 %	0.49 %	0.03 %	0.52 %	0.52 %
Methane	90.4 %	87.4 %	11.8 %	87.4 %	19.5 %	91.3 %	91.3 %
Ethane	4.38 %	4.53 %	2.58 %	4.53 %	6.84 %	4.40 %	4.40 %
Propane	2.29 %	2.95 %	4.17 %	2.95 %	15.04 %	2.27 %	2.27 %
i-Butane	0.68 %	1.25 %	2.80 %	1.25 %	11.92 %	0.65 %	0.65 %
n-Butane	0.66 %	1.52 %	3.79 %	1.52 %	17.30 %	0.62 %	0.62 %
i-Pentane	0.17 %	0.70 %	2.52 %	0.70 %	10.57 %	0.14 %	0.14 %
n-Pentane	0.17 %	0.79 %	3.61 %	0.79 %	12.49 %	0.12 %	0.12 %
n-Hexane	0.44 %	0.32 %	43.62 %	0.32 %	6.25 %	0.02 %	0.02 %
n-Heptane	0.19 %	0.00 %	18.29 %	0.00 %	0.02 %	0.00 %	0.00 %
n-Octane	0.055 %	0.000 %	5.187 %	0.000 %	0.000 %	0.000 %	0.000 %
n-Nonane	0.014 %	0.000 %	1.339 %	0.000 %	0.000 %	0.000 %	0.000 %
n-Decane+	0.002 %	0.000 %	0.214 %	0.000 %	0.000 %	0.000 %	0.000 %

PATENT CLAIMS.

1. Method for production of liquefied natural gas from an incoming feed gas (1), characterised by the following steps:

a) the incoming feed gas is led through a fractionation column (150) where it is cooled and separated into a first overhead gas stream (2), with a reduced content of a first group of hydrocarbons that have a molecular weight higher than pentanes (C5) and enriched with most of the butane (C4) and a second group of hydrocarbons with a lower normal boiling point than butane, and a bottom fraction (3) wherein a third group of hydrocarbons originating from the incoming feed gas, and having a molecular weight from hexanes (C6) and higher is conserved.

b) the first overhead gas stream (2) of the fractionation column is led into a heat exchanger system (110) and is subjected to a partial condensation to form a two-phase fluid, and the two-phase fluid is separated in a suitable separator (160) into a fluid (5) rich in liquefied petroleum gas and pentane (C3-C5) which is re-circulated as cold reflux to the fractionation column (150), and a second overhead gas stream (6), enriched with most of the butane (C4) and hydrocarbons with a lower normal boiling point than butane, wherein said overhead gas stream (6) is reintroduced into the heat exchanger system (110) for liquefaction to liquefied natural gas consisting essentially of methane, ethane, propane and butane, and wherein

c) the cooling circuit for liquefaction of gas in the heat exchanger system comprises an open or closed gas expansion process with at least one gas expansion step.

2. Method according to claim 1, characterised in that the fractionation column (150) and the separator (160) are operated at pressures and temperatures which lead to the complete system (the fractionating column 150 and reflux separator 160) generating a component split/separation point in the normal boiling point range between -12^{0}C and 60^{0}C.

3. Method according to claims 1-2, characterised in that the light key component for the separation is butane (C4) with a normal boiling point between -12^{0}C and 0^{0}C, and the heavy key component is a hexane (C6) component with a boiling point between 50^{0}C and 70^{0}C, whereby the second overhead gas stream (6) of the system will comprise most of the n-butane and hydrocarbons with a lower normal boiling point than n-butane, and the

reject stream (3) of the system comprises most of hexane (C6) and components with a normal boiling point higher than hexane (C6).

4. Method according to claims 1-3, characterised in that the fractionation column (150) and the separator (160) are operated so that pentane (C5, normal boiling point = 28 – 36^{0}C) is a transitional component that is distributed both in the overhead gas stream (6) of the system and the reject stream (3) of the system.

5. Method according to one of the preceding claims, characterised in that the temperature of the feed gas is reduced through the fractionation column (150) so that the temperature of the first overhead gas stream (2) when it is fed into the heat exchanger system (110) is lower than the temperature of the cooling gas stream at the hot end of the heat exchanger system (hot pinch point temperature).

6. Method according to one of the preceding claims, characterised in that a reboiler (135) is connected to the fractionation column (150) to reduce the vapour pressure of the bottom product.

7. Method according to one of the preceding claims, characterised in that the heat exchanger for liquefied natural gas productioncomprises one or more multi-stream heat exchangers.

8. Method according to one of the preceding claims, characterised in that the method is carried out with a closed gas expansion process with at least one nitrogen expander.

9. Method according to one of the preceding claims, characterised in that the method is carried out with a closed hybrid cooling process with methane/nitrogen as a cooling agent, where the cooling agent is used both in the gas phase and in the liquid phase, and where the cooling circuit has at least one gas expander and at least one appliance for expansion of a liquid cooling agent.

10. Method according to one of the preceding claims, characterised in that the method is carried out with an open gas expansion process with at least one gas expander, in which a suitable gas at a higher pressure is used as cooling gas, and where the

expanded gas at a lower pressure is not recompressed for recycling but is used for another purpose.

11. System for carrying out the method according to claims 1-10 comprising a fractionation column (150) for feeding in a feed gas, a heat exchanger system (110) for cooling down and partially condensing a first overhead gas stream of the fractionation column, a separator (160) to separate the partially condensed first overhead gas stream, set up to recycle fluid from the separator to the fractionation column and import this fluid to the upper part of the column as a reflux, and appliance to lead a second overhead gas stream from the separator back to the heat exchanger system for further cooling down and liquefaction to liquefied natural gas, characterised in that the cooling system which is used for cooling down, condensing and liquefying of gas in the heat exchanger system comprises an open or closed gas expansion process with at least one gas expansion step.

12. System according to claim 11, characterised in that the system is designed and configured to separate the feed gas such that the second overhead gas stream (6) of the system will be enriched with most of the butane (C4) and hydrocarbons with a lower normal boiling point than butane, and the bottom product in the fractionation column will be enriched with most of the hexane (C6) and components with a normal boiling point higher than C6.

13. An optimized gas liquefaction system of the gas expansion type for the production of liquefied natural gas from an incoming natural gas stream, characterised in that the system comprises:

a) an open or closed gas liquefaction circuit comprising a gaseous refrigerant, at least one gas expander for cooling the refrigerant by gas expansion, and one or more heat exchangers for heat exchange between the natural gas, liquefied natural gas and refrigerant streams,

b) a fractionation column arranged for receiving the incoming natural gas stream prior to introduction of the natural gas stream into the liquefaction circuit, said fractionation column being further arranged to cool and separate the incoming natural gas stream into a first overhead gas stream, with a reduced content of the hydrocarbons that have a molecular weight higher than pentanes (C5) and enriched with most of the

butane (C4) and hydrocarbons with a lower normal boiling point than butane, and a bottom liquid fraction wherein hydrocarbons having a molecular weight equivalent to or higher than the molecular weight of hexanes (C6) are conserved, and arranged to lead the first overhead gaseous fraction to at least one of the heat exchangers of the liquefaction circuit, whereby the first overhead gas stream is cooled to a two-phase fluid, and

c) a separator arranged for receiving the two-phase fluid and separating the two-phase fluid into a second overhead gas stream-wherein hydrocarbons having a molecular weight from butanes and lighter are conserved, and a liquid component rich in liquefied petroleum gas and pentanes (C3 –C5), and further arranged to return the liquid component back to the fractionation column as a cold reflux liquid and to return the gas component to the liquefaction circuit for further cooling and condensation to liquefied natural gas.

14. A system according to any of claim 13, wherein the liquefaction circuit comprises the gaseous refrigerant at an inlet pressure of 3 – 10 MPa being fed to the heat exchanger or system of heat exchangers and cooled to a temperature between 0 and -120 deg C, and further wherein the cooled gaseous refrigerant is expanded to a pressure between 5% and 40% of the inlet pressure, and then being led back to the heat exchanger or system of heat exchangers to provide cooling.

15. A system according to any of claim 13 or 14, wherein the liquefaction circuit comprises two expansion stages, wherein the gaseous refrigerant at an inlet pressure of 3 – 10 MPa is split in two parts either before or after pre-cooling, and where the parts are pre-cooled to different temperatures before expansion to essentially the same lower pressures and led back to the heat exchanger or system of heat exchangers to provide cooling.

16. A system according to any of claim 13 to 15, wherein cooling in the fractionation column is essentially provided by the reflux liquid from the separator.

17. A system according to any of claim 13 to 16, wherein a reboiler (135) is connected to the fractionation column (150) to reduce the vapour pressure of the bottom product.

18. A system according to any of claim 13 to 17, wherein the first overhead gas stream is cooled into the two-phase fluid by being in heat-exchanging, counter-current relationship with the gaseous refrigerant in one or more heat exchangers of the liquefaction circuit.

19. A system according to any of claim 13 to 18, wherein the liquefaction circuit comprises one or more multi-stream heat exchangers configured in series or parallel, or both.

20. A system according to any of claim 13 to 19, wherein the gas expander essentially isentropically cools the refrigerant.

21. A system according any of claim 13 to 20, wherein the liquefaction circuit comprises a closed gas expansion process with two or more gas expansion stages for essentially isentropically cooling the refrigerant by gas expansion, and where the refrigerant inlet temperature for the second gas expander stage is lower than the refrigerant inlet temperature for the first gas expander stage.

22. A system according to either any of claim 13 to 21, wherein the gaseous refrigerant comprises nitrogen gas, or a mixture of nitrogen and hydrocarbons.