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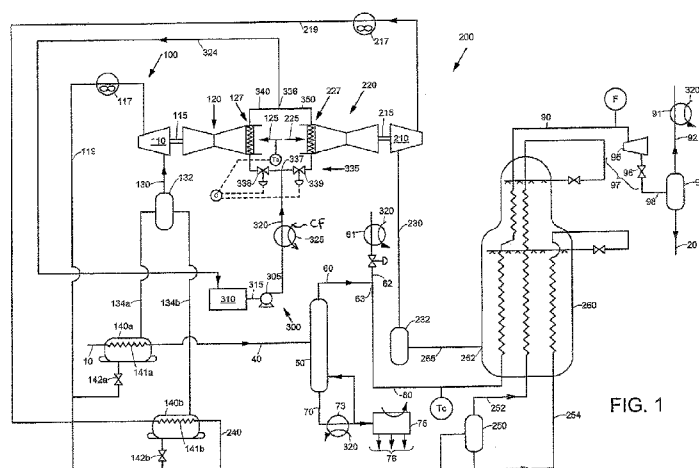


FIG. 1

(57) **Abstract:** A gaseous hydrocarbon stream (10) is cooled to produce a liquefied hydrocarbon stream (20). The gaseous hydrocarbon stream (10) is cooled in one or more heat exchangers (140) using a first refrigerant from a first refrigerant circuit (100) in which said first refrigerant is compressed in a first compressor (110) driven by a first gas turbine (120) having a first inlet air stream (125) and liquefied using a second refrigerant circuit (200) wherein a second refrigerant is compressed in a second compressor (210) driven by a second gas turbine (220) and having a second inlet air stream (225). The cooling duty available in a stream of a chilled coolant (320) is divided over at least first (340) and second (350) parts in accordance with a common input parameter, and one or both of said first and second inlet air streams (125, 225) are cooled with the chilled coolant (320), whereby the cooling duty available in the first part (340) is used to cool the first inlet air stream (125), and the cooling duty available in the second part (350) is used to cool the second inlet air stream (225).

METHOD AND APPARATUS FOR COOLING A GASEOUS HYDROCARBON
STREAM

The present invention relates to a method of cooling a gaseous hydrocarbon stream to produce a liquefied hydrocarbon stream.

A common hydrocarbon stream to be liquefied is natural gas. There are many types of processes that can be used to liquefy natural gas. Many of these processes involve two or more successive refrigerant cycles, often in a cascaded arrangement, for progressively lowering the temperature of the natural gas. Such refrigeration cycles typically comprise refrigerant compressors to recompress the refrigerants in the respective cycles after they have absorbed heat from the natural gas.

The refrigerant compressors may be driven by gas turbines. Such gas turbines comprise an air compressor to compress a stream of inlet air. It is a known characteristic of gas turbines that the power that they can generate decreases with increasing ambient temperature. The decrease in generated power may be mitigated at least in part by chilling the inlet air to the gas turbine.

US patent 6,324,867 to Exxon Mobil discloses a natural gas liquefaction system and process wherein excess refrigeration available in a typical natural gas liquefaction system is used to cool the inlet air to gas turbines in the system to thereby improve the overall efficiency of the system. A coolant (e.g. water) is flowed through coolers positioned in front of the air inlet of each gas turbine. The coolant, in turn, is cooled with propane taken from a refrigerant circuit in

the system which is used to initially cool the natural gas which is to be liquefied. The coolant flows through the coolers in a parallel fashion, because the cooled coolant is split to flow to each cooler and recombined downstream of the coolers. A control valve is provided in each line after the split, and controlled independently by an unspecified property of the inlet air in the corresponding gas turbine.

A drawback of this method is that it does not take into account which of the gas turbines is presenting the most severe constraint on the LNG production.

The present invention provides a method of cooling a gaseous hydrocarbon stream to produce a liquefied hydrocarbon stream, comprising:

- cooling the gaseous hydrocarbon stream in one or more heat exchangers using a first refrigerant from a first refrigerant circuit in which said first refrigerant is compressed in a first compressor driven by a first gas turbine having a first inlet air stream, said cooling providing a cooled hydrocarbon stream;
- liquefying the cooled hydrocarbon stream using a second refrigerant, which second refrigerant is compressed in a second compressor driven by a second gas turbine having a second inlet air stream, and cooled at least by heat exchanging with said first refrigerant from the first refrigerant circuit, said liquefying providing a liquefied hydrocarbon stream;
- providing a stream of a chilled coolant;
- dividing the cooling duty available in the chilled coolant over at least first and second parts in accordance with a common input parameter;
- cooling one or both of said first and second inlet air streams with the chilled coolant, whereby the cooling

duty available in the first part is used to cool the first inlet air stream, and the cooling duty available in the second part is used to cool the second inlet air stream.

5 Moreover, an apparatus is provided, arranged to carry out these process steps.

The invention further provides an apparatus for cooling a gaseous hydrocarbon stream to produce a liquefied hydrocarbon stream, comprising:

- 10 - a first refrigerant circuit comprising a first refrigerant, a first compressor, a first gas turbine coupled to the first compressor to drive the first compressor, and a first inlet air stream to the first gas turbine; the first compressor arranged to compress said
- 15 first refrigerant;
- a second refrigerant circuit comprising a second refrigerant, a second compressor, a second gas turbine coupled to the second compressor to drive the second compressor, and a second inlet air stream to the second
- 20 gas turbine; the second compressor arranged to compress said second refrigerant;
- one or more first heat exchangers arranged to receive and cool the gaseous hydrocarbon stream and the second refrigerant, using said first refrigerant from said
- 25 cooling providing a cooled hydrocarbon stream and a cooled second refrigerant stream;
- one or more second heat exchangers arranged to receive and liquefy the cooled hydrocarbon stream using the cooled second refrigerant stream, so as to provide a
- 30 liquefied hydrocarbon stream;
- a stream of a chilled coolant;

- a divider to divide the chilled coolant over at least first and second parts in accordance with a common input parameter;

- a first inlet air cooling heat exchanger arranged in the first inlet air stream to cool the first inlet air stream with the first part of the chilled coolant;

- a second inlet air cooling heat exchanger arranged in the second inlet air stream to cool the second inlet air stream with the second part of the chilled coolant.

The invention will now be further illustrated by way of example and with reference to one or more figures in the accompanying drawing, wherein

Fig. 1 schematically shows an apparatus and method for cooling and liquefying a hydrocarbon stream according to an embodiment of the invention;

Fig. 2 schematically shows an example of a chilling refrigerant circuit for actively chilling of the coolant fluid;

Fig. 3 schematically shows an alternative drive scheme that can be used in the invention;

Fig. 4 schematically shows another alternative drive scheme that can be used in the invention; and

Fig. 5 schematically shows still another alternative drive scheme that can be used in the invention.

In the description of these figures hereinbelow, a single reference number has been assigned to a line as well as a stream carried in that line. The same reference numbers refer to similar components, streams or lines.

It is presently proposed to divide the cooling duty available in a chilled coolant over at least first and second parts in accordance with a common input parameter, and to cool at least first and second gas turbine inlet air streams with the chilled coolant, whereby the cooling

duty available in first part is used to cool the first inlet air stream and the cooling duty available in the second part is used to cool the second inlet air stream.

By dividing the cooling duty available in accordance with a common input parameter, a better optimum in the division of available cooling duty over the at least two inlet air streams can be achieved.

For instance, if the common input parameter is a parameter representative of ambient temperature, the division of cooling duty can be made in accordance with ambient temperature. Depending on ambient temperature, the compression power needed in the first and second compressors in a hydrocarbon cooling process, as well as the available power in the first and second gas turbines, shifts. At low ambient temperature the condensing pressure of the first refrigerant is relatively low and hence relatively less compression power is needed in the first compressor compared to the second compressor, making the compression power in the main refrigerant circuit the limiting factor in the amount of LNG that is produced. In that case, the division of cooling duty can be made leaning towards favoring the cooling duty in the second part to increase the compression power available in the second compressor.

However, as the ambient temperature increases, the production limitation starts shifting towards the first compressor, because of increasing discharge pressure of the first compressor. Then the division can be made differently, favoring less the second part and thereby freeing up cooling duty for the first part. Hereby the LNG production can be maximised and/or the power consumption for a fixed production rate of LNG minimized.

The cooling duty available in the chilled coolant may be divided in any ratio between the first and second parts, ranging from 0:1 to 1:0. For instance, during cold ambient conditions the duty attributed to the first part may be zero such that the full available cooling duty in the chilled coolant can be used to cool the second air inlet stream.

Suitably, said dividing of the cooling duty in accordance with the common input parameter comprises deriving an optimum ratio of division based on the common input parameter, and controlling the ratio at which the cooling duty available in the chilled coolant is actually divided between the first and second parts whereby causing this ratio to be changed to or be maintained at the derived optimum ratio.

For the purpose of the present specification, "chilled coolant" is understood to be a fluid that has a temperature lower than that of the ambient air temperature. The chilled coolant can be prepared by actively chilling the fluid, using refrigeration duty from any refrigerant or cold stream, including refrigeration duty taken from the first refrigerant circuit and/or refrigeration duty taken from the second refrigerant circuit, and/or refrigeration duty from any type of refrigerant circuit.

There are also other cold streams available in a hydrocarbon liquefaction process, which are not cycled in a refrigerant circuit. Examples include the liquid bottom stream of an extraction column and/or a fractionation column and/or an overhead stream from a fractionation column, a stream of end-flash gas that may be generated when letting down the pressure of the liquefied hydrocarbon stream, a stream of boil-off gas that may be

evaporated off of the liquefied hydrocarbon while in storage. Typical examples of extraction columns used in a hydrocarbon liquefaction line-up include a simple gas/liquid phase separator vessel, or a more advanced distillation column such as a scrub column and a natural gas liquids extraction column, which typically operates at a lower pressure than a scrub column. Typical fractionation columns in use in a natural gas liquids fractionation train are a demethanizer, a deethanizer, a depropanizer and a debutanizer.

One or more other common input parameters may be used instead of or in addition to the parameter indicative of ambient temperature. Suitable examples include parameters representative of: first compressor discharge pressure; cut point temperature between first and second refrigerant cycle; first compressor adsorbed power; second compressor absorbed power; difference between first or second gas turbine power output; flow rate of liquefied hydrocarbon.

Referring now to Figure 1, there is shown an apparatus for cooling a gaseous hydrocarbon stream 10 to produce a liquefied hydrocarbon stream 20. The apparatus comprises a first refrigerant circuit 100 and a second refrigerant circuit 200.

The first refrigerant circuit 100 comprises a system of lines containing a first refrigerant that can be cycled through the circuit. The second refrigerant circuit comprises a separate system of lines, containing a second refrigerant that can be cycled through the second refrigerant circuit 200.

The first refrigerant circuit 100 comprises a first compressor 110. A first gas turbine 120 is coupled to the first compressor 110 via a first drive shaft 115, to

directly drive the first compressor 110. The first gas turbine 120 is associated with a first inlet air stream 125 to the first gas turbine 120. The first compressor 110 is arranged to compress the first refrigerant in line 130. As a precaution, the refrigerant in line 130 may have passed through an optional suction drum 132 to ensure that no liquid constituents are fed into the first compressor 110.

The second refrigerant circuit 200 comprises a second compressor 210 and a second gas turbine 220. The second gas turbine 220 is coupled to the second compressor 210 via a second drive shaft 215, to drive the second compressor 210. The second gas turbine 220 is associated with a second inlet air stream 225 to the second gas turbine. The second compressor 210 is arranged to compress the second refrigerant in line 230. As a precaution, the refrigerant in line 230 may have passed through an optional suction drum 232 to ensure that no liquid constituents are fed into the second compressor 210.

The respective first and second gas turbines 120, 220 are each associated with an inlet air cooling heat exchanger, in the form of a first inlet air cooling heat exchanger 127 and a second inlet air cooling heat exchanger 227, respectively. These inlet air cooling heat exchangers are arranged in the first respectively second inlet air stream 125, 225 to cool the first and second inlet air streams. Optionally, filters may be provided in the first and second inlet air streams 125, 225 (not shown) to filter the air before it is compressed in the respective gas turbine 120, 220. Separators (not shown), such as vertical vane type separators, and associated drain facilities may be provided downstream of the inlet

air cooling heat exchangers 127, 227 to remove moisture that may develop during the cooling of the inlet air stream(s). Drain facilities may also be provided in the air cooling heat exchangers 127, 227 to drain of moisture from these heat exchangers.

The suction inlet of the second compressor 210 is connected to a second refrigerant outlet 262 of a second heat exchanger 260 via the line 230 and the optional suction drum 232. The second heat exchanger 260 is one of one or more second heat exchangers, arranged to receive and liquefy a cooled hydrocarbon stream in line 80, so as to provide a liquefied hydrocarbon stream 20.

The outlet of the second compressor 210 is connected to line 119 that is provided with one or more ambient coolers 217.

The outlet of the first compressor 110 is connected to one or more first heat exchangers 140a, 140b via a refrigerant line 119. Upstream of the one or more first heat exchangers 140a, 140b, one or more ambient coolers 117 are provided in the refrigerant line 119. Pressure reduction devices 142a, 142b are provided upstream of the one or more first heat exchangers 140a, 140b to regulate the pressure in these heat exchangers. The one or more heat exchangers 140a, 140b have refrigerant outlets that are connected to the first refrigerant compressor 110 via lines 134a and 134b. In the embodiment shown in Figure 1, the lines 134a and 134b connect to the first refrigerant compressor 110 via the optional suction drum 132.

In the embodiment as shown, two of the one or more heat exchangers 140a, 140b are arranged in a parallel configuration, and each have a single warm tube or warm tube bundle 141a, 141b. Alternatively, it is possible to arrange two parallel warm tubes or warm tube bundles in

one heat exchanger. This may be in various types of heat exchangers, such as the kettle type as presently shown in Figure 1 and spool-wound type as for instance shown in US Patent 6,370,910.

5 One of the one or more first heat exchangers is arranged to receive and cool the gaseous hydrocarbon stream 10. This one will be referred to as first hydrocarbon feed heat exchanger 140a. Optionally, there are one or more other first heat exchangers arranged in
10 the hydrocarbon feed line 10 upstream of the first hydrocarbon feed heat exchanger 140a, to be operated at higher pressures than the first hydrocarbon feed heat exchanger 140a.

 Line 40 downstream of the first hydrocarbon feed heat
15 exchanger may be connected directly to line 80 that connects to the second heat exchanger 260 in order to provide the cooled hydrocarbon stream to line 80. However, as shown in the embodiment of Figure 1, the line 40 is connected to withdrawing means in the form of an
20 optional gas/liquid separator 50 that is provided to receive the hydrocarbon stream 40 at approximately the hydrocarbon feed gas pressure, after it has passed through the first hydrocarbon feed heat exchanger 140a. The optional gas/liquid separator may suitably be a
25 natural gas liquids extraction column and/or employed for the purpose of extraction of natural gas liquids. Typical examples of extraction columns used in a hydrocarbon liquefaction line-up for extraction of natural gas liquids include a simple gas/liquid phase separator
30 vessel, or a more advanced distillation column such as a scrub column and a natural gas liquids extraction column, which typically operates at a lower pressure than a scrub column. In the embodiment shown in Figure 1, the

optional gas/liquid separator is provided in the form of a scrub column.

The optional gas/liquid separator 50 has an overhead outlet for discharging a vaporous overhead stream 60 and a bottom outlet for discharging a liquid bottom stream 70. Line 60 for the vaporous overhead stream 60 may be connected to line 80 to provide the cooled hydrocarbon stream in line 80. A splitter 63 may be provided in line 60 or line 80, to draw off a fuel gas stream 62 from the vaporous overhead stream 60.

The liquid bottom stream 70, which may typically comprise C₂ to C₄ constituents as well as C₅+, may be connected to an optional fractionation train 75 to fractionate at least a part of the bottom stream 70 into fractionation product streams 76. A bottom stream heat exchanger 73 may optionally be provided to add heat to at least a part of the bottom stream 70. Part of the bottom stream 70 may be fed back to the optional gas/liquid separator 50 as a reboiled stream 74, preferably comprising, more preferably consisting of, vapour to function as stripping vapour in the optional gas/liquid separator 50. The heat source may be formed by stream 320, for instance by employing the bottom stream 70 as cold fluid CF. An advantage of this arrangement is that the part of the bottom stream 70 that needs to be fed back to the optional gas/liquid separator 50 is cold and needs to receive heat to generate the reboiled stream 74, while the coolant fluid is available and needs to be chilled.

Another one of the one or more first heat exchangers, which will hereinafter be referenced as first second refrigerant heat exchanger 140b, is arranged to receive the second refrigerant from line 219. To this end, line

219 is connected to the warm tube (or warm tube bundle) 141b. Optionally, there are one or more other first heat exchangers arranged in the second refrigerant line 219 upstream of the first second refrigerant heat exchanger 140b, to be operated at higher pressures than the first second refrigerant heat exchanger 140b. Downstream of the first second refrigerant heat exchanger an optional refrigerant gas/liquid separator 250 is provided to receive the cooled second refrigerant stream 240 after it has passed through the first second refrigerant heat exchanger 140b and separate it into cooled at least by heat exchanging with said first refrigerant from the first refrigerant circuit.

The cooled hydrocarbon stream 80 and the second refrigerant stream 240 (or vapour and liquid second refrigerant streams 252 respectively 254) are connected to the one or more second heat exchangers 260, to further cool and liquefy the cooled hydrocarbon stream 80 to obtain at least an intermediate liquefied hydrocarbon stream 90 and an at least partially or fully evaporated refrigerant stream 265 at the outlet 262.

Line 90 may be connected to depressurizing equipment comprising optional phase separation equipment to separate flash vapour from the remaining liquid. This may be employed as withdrawal means in order to withdraw a fraction from the hydrocarbon stream that may be used as stream CF in chiller 325 to provide the cold coolant fluid 320. There are various systems known in the art. As example, the depressurizing equipment is here embodied as one or more expansion devices 97 to produce a depressurized stream 98 followed by a phase separator 99. The expansion devices may be embodied in the form of an isentropic expander such as work-expander 95 which may be

provided in the form of a turbine, and/or an isenthalpic expander such as a Joule-Thomson valve 96. In the embodiment of Figure 1, the isenthalpic expander 96 is suitably be provided downstream of the isentropic expander 95.

Still referring to Figure 1, the apparatus further comprises a coolant circuit 300, wherein a coolant fluid can be circulated for chilling the first and/or second inlet air streams 125, 225. In the embodiment as shown, there is provided a storage tank 310 wherein the coolant fluid can be stored. The coolant fluid is preferably a liquid and/or inflammable for safety reasons. Suitable coolants include water and brine, possibly admixed with an anti-freezant such as a glycol and/or a corrosion inhibitor.

The coolant circuit 300 further comprises means for actively chilling the fluid to provide a chilled coolant 320. In the embodiment of Figure 1, a chiller 325 is provided for that purpose. The chiller 325 is arranged to receive a cold fluid CF capable of withdrawing heat from the coolant fluid and thereby to provide the chilled coolant in line 320. The cold fluid CF can be obtained from numerous sources, as will be further illustrated hereinbelow.

The cold fluid CF may be obtained from a single source or it may comprise a mixture of fluids from two or more sources. Alternatively, instead of one cold fluid CF, there may be two or more cold fluids, each arranged to remove heat from the coolant fluid in line 320. In this case, it may be a suitable choice of design to use a plurality of chillers, either arranged in parallel or in series in line 320. Suitably, a separate chiller is provided for each source of cold fluid.

To assist the flow of the fluid in the coolant circuit, a pump 305 is provided. The pump may be provided anywhere in the circuit. Suitably, as proposed in the embodiment of Figure 1, the pump 305 has its low pressure inlet connected to the storage tank 310 via line 315 and its high-pressure outlet connected to the chiller 325.

Downstream of the chiller 325 there is provided a divider 335, to divide the chilled coolant 320 over at least a first part 340 and a second part 350. The divider will be discussed in more detail below.

The first inlet air cooling heat exchanger 127 is arranged in line 340 to cool the first inlet air stream 125 with the first part of the chilled coolant. The second inlet air cooling heat exchanger 227 is arranged in the second inlet air stream to cool the second inlet air stream with the second part of the chilled coolant. The divider as shown in Figure 1 comprises a junction 337, such as a T-piece, a first flow control valve 338 in line 340, and a second flow control valve 339 in line 350. Both control valves have been depicted as controllable valves, to provide freedom to add other streams. However, the skilled person will understand that in the apparatus as depicted in Figure 1 only one of both flow control valves needs to be controllable because there are only two lines downstream of the junction 337.

The apparatus in the embodiment as shown in Figure 1 further comprises a controller C. In a preferred embodiment, the controller is arranged to receive a signal representative of a common input parameter. The controller is further arranged to determine an optimum division of the cooling duty available in the chilled refrigerant over the first and second parts 340, 350 based on the common input parameter.

As represented in Figure 1, the common input parameter is indicative of ambient temperature. The signal may be provided from a temperature sensor Ta, which is for instance located in one or more of the inlet air streams 125, 225. Means, for example controller C, are provided for sending a control signal to one or more of the flow control valves 338, 339. The control signal may be provided in the form of a valve setting set point.

Alternatively, the signal may be provided to represent a common input parameter that is indicative of another relevant entity. For instance, the common input parameter may be indicative of first compressor discharge pressure.

The apparatus works as follows. The gas turbines 120 and 220 each take in an inlet air stream and a fuel stream and provide mechanical power on the respective drive shafts 115, 215. The drive shafts are mechanically coupled to respective first and second compressors 110, 210 and thus the compressors are driven.

The first refrigerant in the first refrigerant circuit 100 is compressed in compressor 110, cooled against ambient in one or more coolers 117 and distributed over one or more first heat exchangers 140a, 140b. Typically, cooling of the first refrigerant in the cooler(s) 117 causes it to partially, preferably fully, condense. Upstream of each of the first heat exchangers the first refrigerant the pressure is let down in the reduction devices 142a, 142b. The first refrigerant is then allowed to evaporate in the first heat exchangers 140a, 140b by drawing heat from the warm tubes or tube bundles 141a, 141b. The evaporated first refrigerant is led back to the first compressor 110.

A gaseous hydrocarbon stream 10 cooled in one or more of the first heat exchangers, as shown in Figure 1 by passing the gaseous hydrocarbon stream through the warm tube 141a in first hydrocarbon feed heat exchanger 140a, to produce a partially condensed hydrocarbon stream 40.

The second refrigerant in the second refrigerant circuit 200 is compressed in compressor 210, cooled against ambient in one or more coolers 217 and then further cooled in one or more of the first heat exchangers. As depicted in Figure 1, the further cooling of the second refrigerant is achieved by passing it through warm tube 141b in first second refrigerant heat exchanger 140b where it is cooled at least by heat exchanging with said first refrigerant, to produce a partially condensed second refrigerant stream 240.

The partially condensed second refrigerant stream 240 is separated into vapour and liquid second refrigerant phases 252 respectively 254. These streams are then condensed and sub-cooled, respectively subcooled, in the one or more second heat exchangers 260 in a manner well known in the art.

The partially condensed hydrocarbon stream 40 is separated into vaporous overhead stream 60 and liquid bottom stream 70. Optionally, at least a part of the bottom stream 70 is warmed in bottom stream heat exchanger 73 and at least part of the warmed bottom stream 74 may be fed back to the optional gas/liquid separator 50 as a reboiled stream. The remaining part is typically led to the fractionation train 75 where it is fractionated into one or more fractionation product streams. Typical fractionation columns in use in a natural gas liquids fractionation train are a

demethanizer, a deethanizer, a depropanizer and a debutanizer.

The vaporous overhead stream 60 is fed into line 80 as a cooled hydrocarbon stream 80. The cooled hydrocarbon stream 80 is then fed to one or more of the second heat exchangers 260 in a manner known in the art where it is liquefied using the second refrigerant. Herewith is produced an intermediate liquefied hydrocarbon stream 90.

This intermediate liquefied hydrocarbon stream 90 may be depressurized in the one or more expansion devices 97 and the depressurized stream 98 led to phase separator 99, where any vaporous constituents, mainly flash vapour, are separated from the liquid hydrocarbons in stream 98. The liquid hydrocarbons are removed from the phase separator 99 as liquefied hydrocarbon product stream 20, the vaporous constituents are drawn from the phase separator 99 as end flash stream 92.

The coolant fluid in the storage tank 310 is pumped or otherwise led to chiller 325, wherein it is actively chilled to provide chilled coolant 320 by heat exchanging against cold fluid CF. The cooling duty available in the chilled coolant 320 is used to chill the inlet air stream of at least one of the gas turbines.

The available cooling duty can suitably be divided over at least first and second parts. The cooling duty may for instance be divided by physically splitting the chilled coolant 320 over two or more part streams, such as two part streams 340, 350 in the embodiment of Figure 1. The first part stream 340 is used to cool the first inlet air stream 125 and the second part stream 350 is used to cool the second inlet air stream 225.

The dividing of the cooling duty may be done in accordance with a common input parameter. This allows to

control the division of available cooling duty over the at least two inlet air streams in the best possible way. Of course, it is possible that at times all of the chilling duty is sent to only one of the part streams, depending on the common input parameter. Preferably, the control of the division of the cooling duty in accordance with the common input parameters allows control over the power balance between the various refrigerant circuits.

Suitably, the common input parameter allows the controller C to determine which refrigeration circuit is the constraining refrigeration circuit in terms of not being able to deliver enough cooling duty to allow one or more of the other refrigeration circuits to operate at a higher (or full) capacity. By then providing relatively more chilling duty to the inlet air stream(s) of the turbine(s) driving the constraining refrigerant circuit, it is possible to selectively increase the gas turbine efficiency (resulting in increased shaft power output) of the constraining gas turbine relative to the other gas turbines driving other refrigerant circuits. This then allows to increase the production rate of the liquefied hydrocarbon product (or to produce the liquefied hydrocarbon product stream at lower specific energy consumption).

Suitably the common input parameter is indicative of the ambient temperature, such as the temperature T_a of one or both of the inlet air streams 125, 225. A consequence of the cascaded refrigeration arrangement of Figure 1 is that, as the ambient temperature increases, relatively more cooling duty is needed from the first refrigerant circuit 100 relative to the cooling duty needed from the second refrigerant circuit 200. The controller can then cause relatively more cooling duty

from the chilled coolant to be made available for cooling of the first inlet air stream 125. Depending on the design of the process, it may be possible that all cooling duty from the chilled coolant is made available to cooling of the first inlet air stream 125, particularly in situations that the first gas turbine power output is constraining the process. However, particularly when no or insufficient additional (helper) driver power is provided to supplement the gas turbine drive power for the second compressor 210, it is likely preferable that at least some of the cooling duty is always used for cooling the second inlet air stream 225, even when the first gas turbine power output is constraining, in order to ensure that the second compressor is not driven out of its operating window into surge as a result of too low a drive power.

At relatively lower ambient temperature, the second refrigerant circuit 200 may become the constraining circuit and the controller may cause relatively more cooling duty from the chilled coolant to be made available for cooling of the second inlet air stream 225. At very cold ambient temperatures the controller may cause to send all cooling duty from the chilled coolant to be made available for cooling of the second inlet air stream 225.

Similar effects may be achieved by using another common input parameter, such as for example a common input parameter that is indicative of one of the group of: first compressor discharge pressure; first gas turbine load/poweroutput; second gas turbine load/poweroutput; first gas turbine fuel gas valve opening; second gas turbine fuel gas valve opening; cut point temperature T_c between first and second refrigerant

cycle; first compressor adsorbed power; second compressor
absorbed power; difference between first or second gas
turbine power output; flow rate of liquefied hydrocarbon.
The latter is symbolically indicated in Figure 1 by the
5 flow sensor F, which may feed its signal to controller C
(not shown) similar to sensor Ta.

After having cooled the first and/or second inlet air
streams 125, 225, the coolant may be recombined and led
to the storage tank 310 for re-use.

10 The inlet air streams 125, 225 are preferably not
cooled to lower than about 5 °C to ensure that formation
of ice is avoided.

The cooling duty for actively chilling of the coolant
fluid in the one or more chillers 325 may be obtained
15 from a wide variety of sources. For instance, it may use
chilling duty provided by a thermally driven chilling
process. Particularly, the one or more chillers 325 may
comprise one or more thermally driven chillers. The
thermally driven chilling process and/or the thermally
20 driven chillers may be operated using waste heat from the
liquefaction process, e.g. the waste heat from one or
more of the first and second gas turbines 120, 220.

Thermally driven chillers are known in the art. A
relatively common example is formed by the group
25 consisting of absorption chillers. One example of an
absorption chilling is based on evaporating liquid
ammonia in the presence of hydrogen gas, providing the
cooling. More common in large commercial plants are so-
called lithium/bromide absorption chillers. A
30 lithium/bromide absorption chiller uses a solution of
lithium/bromide salt and water. Another example of
thermally driven chillers known in the art is formed by
the group consisting of adsorption chillers. Still

another example is formed by the group consisting of absorption heat pumps. Their principle of operation is similar to absorption chillers.

Alternatively or in addition to thermally driven
5 chilling, the actively chilling of the coolant fluid may use a chilling refrigerant from a dedicated mechanically driven chilling refrigerant circuit. As illustrated in Figure 2, the dedicated chilling refrigerant circuit 380 is provided with its own compressor 381 and means for
10 rejecting heat from the compressed chilling refrigerant to the ambient such as cooler 382. The compressor 381 may be driven by any suitable driver 383, suitably an electric motor but not necessarily so. The chiller 325 is depicted in the form of a kettle. A Joule Thomson valve
15 386 is provided between the kettle 325 and the cooler 382, downstream of an optional accumulator 385. A knockout drum 384 may be provided between the kettle 325 and the suction inlet of the compressor 381 as a precaution. The chilling refrigerant may consist of any
20 component or mixture suitable for removing heat at approximately the temperature level of the ambient temperature. Examples include butane, iso-butane, propane, ammonia.

Alternatively or in addition thereto, it may use
25 refrigeration duty from a stream that is already available in the liquefaction line-up. For instance, it may use refrigeration duty taken from the first refrigerant circuit and/or the second refrigerant circuit.

30 Of these two, it is preferred to use refrigeration duty from the first refrigerant circuit 100 because the refrigerant in the first refrigeration circuit 100 is generally more efficient at removing heat at the desired

temperature level of the chilling coolant. This can or instance be done by providing chiller 325 in the form of a kettle wherein the first refrigerant from line 119 is evaporated at a desired suitable pressure level.

5 Downstream of the chiller 325 the first refrigerant may be recompressed, e.g. via a dedicated compressor and then recombined with the first refrigerant in the first refrigerant circuit downstream of first refrigerant compressor 110, or via first refrigerant compressor 110 itself for instance by feeding the refrigerant downstream
10 of chiller 325 to the knock out drum 132.

Refrigeration duty from the second refrigerant circuit may be used by allowing a slip stream from for instance line 240 to evaporate in and/or pass through
15 chiller 325 at a desired pressure level as cold stream CF. The slip stream may also be drawn from other suitable places in the second refrigerant circuit 200, such as from the liquid second refrigerant stream in line 254 if optional refrigerant gas/liquid separator 250 is present.
20 Irrespective of the origin of the slipstream, downstream of the chiller the slip stream may be fed back to the second compressor 210 and/or recompressed using a dedicated compressor.

Optionally, the controller C is arranged to control
25 the selection of the source of refrigeration duty between first and second refrigeration circuit based on the refrigeration circuit that is the least constraining of the two.

In addition to and/or instead of one or more of the
30 refrigerant streams indicated above, the coolant may be chilled using refrigeration duty provided by any other cold stream available in the process. For instance, if gas/liquid phase separator 50 is present, the cold fluid

CF may be derived from or contain the liquid bottom stream 70. In this case, optional heat exchanger 73 may be in communication with stream 320 or the optional heat exchanger 73 may be one of the one or more chillers 325.

5 Other examples of cold streams that may be used to provide part of or all of the refrigeration duty for the active cooling of the coolant include fuel gas stream 62, end flash stream 92, and any cold stream from (optional) fractionation train 75. Figure 1 shows symbolically
10 optional chillers 61 and 91 that could be used as chiller(s) 325 or be otherwise positioned in communication with line 320. Boil off gas, for instance from a storage tank wherein the liquefied hydrocarbon stream 20 may be stored, may also be used to provide part
15 of or all of the refrigeration duty for the active cooling of the coolant.

 In alternative embodiments, the second refrigerant may be fully condensed after its cooling against the first refrigerant. In such embodiments, obviously the
20 optional refrigerant gas/liquid separator 250 need not be provided. There are also alternative embodiments wherein the second refrigerant is not fully condensed but wherein nevertheless no gas/liquid phase separation is needed, for instance because full condensation is achieved in a
25 subsequent heat exchanging against a further refrigerant or by auto-cooling.

 The apparatus may have various modifications compared to what is specifically depicted in Figure 1. Some modifications and alternatives have already been
30 mentioned hereinabove. In another optional modification, for instance, first compressor 110 may have a multiple of inlets at different pressure levels in a manner known in the art. The first compressor 110 and/or the second

compressor 210 may each be embodied in the form of two or more successive or parallel arranged frames, in a manner known in the art.

5 First and/or second gas turbines 120, 220 may be of an aeroderivative type, such as for example a Rolls Royce Trent 60 or RB211, and General Electric LMS100TM, LM6000, LM5000 and LM2500. The presently proposed inlet air chilling is particularly advantageous when using aeroderivative type turbines, as this can replace the need for helper drivers (typically a steam turbine or electric motor) to compensate for power loss.

10 Alternatively, the first and/or second gas turbines may be of a heavy industrial frame type, such as for example a General Electric Frame 6, Frame 7 or Frame 9 to enhance the efficiency, although in this case an additional driver may still need to be provided for starting up the turbine. Clearly, equivalent gas turbines from other manufactures may be employed as well.

20 Optionally, (not shown), an overhead heat exchanger may be provided in line 60 in a way known in the art. Such an overhead heat exchanger may form part of the one or more first heat exchangers, and it may for instance be connected to line 119 to obtain a fraction of the first refrigerant. Where such an overhead heat exchanger is provided in line 60, an optional overhead gas/liquid separator is provided downstream of the overhead heat exchanger in order to remove any condensed fraction from stream downstream of the overhead heat exchanger. The vapour outlet of the overhead gas/liquid separator may then be connected to line 80 to provide the cooled hydrocarbon stream. The bottom liquid outlet of the overhead gas/liquid separator may be connected to the gas/liquid separator 50 to feed back at least a portion

of the condensed fraction as a reflux stream. The fuel gas stream 62 may be drawn from the vapour stream.

In an alternative embodiment, the optional gas/liquid separator 50 is located upstream of the first hydrocarbon feed heat exchanger 140a. The overhead outlet of the gas/liquid separator could in such an alternative embodiment be connected to line 10 in Figure 1, and line 40 could be connected directly to line 80 to provide the cooled hydrocarbon stream to the second heat exchanger 260. Such embodiments may have an expander upstream of the optional gas/liquid separator 50, and typically one or more recompressors and/or booster compressors upstream of the first hydrocarbon feed heat exchanger 140a, and/or other heat exchangers to pre-cool the feed to the optional gas/liquid separator 50. Such embodiments are known in the art and need not be further detailed here.

In the embodiment as shown in Figure 1, the first refrigerant is a single component refrigerant consisting essentially of propane, while the second refrigerant is a mixed refrigerant. A mixed refrigerant or a mixed refrigerant stream as referred to herein comprises at least 5 mol% of two different components. The mixed refrigerant may contain two or more components selected from the group consisting of: nitrogen, methane, ethane, ethylene, propane, propylene, butanes. A common composition for a mixed refrigerant can be:

Nitrogen	0-10 mol%
Methane (C1)	30-70 mol%
Ethane (C2)	30-70 mol%
Propane (C3)	0-30 mol%
Butanes (C4)	0-15 mol%

The total composition comprises 100 mol%.

However, the methods and apparatus disclosed herein may further involve the use of one or more other refrigerants, in separate or overlapping refrigerant circuits or other cooling circuits. Moreover, the first refrigerant may be a mixed refrigerant (such as described for instance in US Pat. 6,370,910) and/or the second refrigerant may be a single component refrigerant (such as consisting essentially of ethane, ethylene, methane or nitrogen). The invention may also be applied in the so-called Axens LIQUEFIN process, such as described in for instance the paper entitled "LIQUEFIN: AN INNOVATIVE PROCESS TO REDUCE LNG COSTS" by P-Y Martin *et al*, presented at the 22nd World Gas Conference in Tokyo, Japan (2003).

The gaseous hydrocarbon stream 10 to be cooled and liquefied may be derived from any suitable gas stream to be cooled and liquefied, such as a natural gas stream obtained from natural gas or petroleum reservoirs or coal beds. As an alternative the gaseous hydrocarbon stream 10 may also be obtained from another source, including as an example a synthetic source such as a Fischer-Tropsch process.

When the gaseous hydrocarbon stream 10 is a natural gas stream, it is usually comprised substantially of methane. Preferably the gaseous hydrocarbon stream 10 comprises at least 50 mol% methane, more preferably at least 80 mol% methane.

Depending on the source, natural gas may contain varying amounts of hydrocarbons heavier than methane such as in particular ethane, propane and the butanes, and possibly lesser amounts of pentanes and aromatic

hydrocarbons. The composition varies depending upon the type and location of the gas.

Conventionally, the hydrocarbons heavier than methane are removed as far as needed to produce a liquefied hydrocarbon product stream in accordance with a desired specification. Hydrocarbons heavier than butanes (C4) are removed as far as efficiently possible from the natural gas prior to any significant cooling for several reasons, such as having different freezing or liquefaction temperatures that may cause them to block parts of a methane liquefaction plant.

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

It will be understood that the present invention is applicable not only to the drive scheme as specifically illustrated in Figure 1, but to other drives schemes as well. Figures 3 to 5, which are not intended to form an exclusive list, illustrate some possible alternative options. Similar and/or various other options are also briefly depicted in for instance in LNG-14 paper entitled "REDUCING LNG CAPITAL COST IN TODAY'S COMPETITIVE ENVIRONMENT" by Mark J. Roberts *et al*, paper 2.6 (2004).

For instance, Figure 3 shows the first refrigerant in line 130 being offered to a plurality of inlets in the first compressor 110 each at a different pressure. The

compressor 210 for compressing the second refrigerant is embodied in successively arranged low pressure second refrigerant compressor 210a and high pressure second refrigerant compressor 210b, both being driven on a single axis 215 by the second gas turbine 220. The second refrigerant in line 230 is fed to the low pressure second refrigerant compressor 210a and the high pressure second refrigerant compressor 210b discharges into line 219.

As illustrated in Figure 4, the invention can be applied to the so-called Split-MRTM introduced by Air Products and Chemicals Inc and briefly described in for instance LNG-13 paper entitled "REDUCING LNG COSTS BY BETTER CAPITAL UTILIZATION" by Dr. Yu Nan Liu *et al*, paper PS5-4 (2001). In essence, the second compressor 210 driven by the second gas turbine 220 functions as the low pressure second refrigerant compressor 210a of Figure 3 but the first gas turbine 120 drives both the first compressor 110 as well as a second second compressor 211 which functions as the high pressure second refrigerant compressor 210b of Figure 3. Thus, the second refrigerant in line 230 is fed to second compressor 210, and the second second compressor 211 discharges into line 219.

Figure 5 illustrates an embodiment using an auxiliary second compressor 410 which is driven by a third gas turbine 420. Like Figure 4, the second compressor 210 is driven by the second gas turbine 220 and functions as the low pressure second refrigerant compressor 210a of Figure 3, but in this case the third gas turbine 420, via shaft 415, drives the auxiliary second compressor 410 which functions as the high pressure second refrigerant compressor 210b of Figure 3. Thus, the second refrigerant in line 230 is fed to second compressor 210, and the auxiliary second compressor 410 discharges into line 219.

As depicted in Figure 5 only the first and second gas turbines inlet air streams 125 and 225 are cooled, whereas the third gas turbine inlet air stream 425 is provided to the third gas turbine at ambient temperature and not cooled. Alternative embodiments also cool the third inlet air stream 425 to the third gas turbine 420 (either sharing cooling duty from the chilled coolant 320 or by a separate cooling source), or cool the third inlet air stream 425 instead of the second inlet air stream 225.

An intercooler, such as an air-cooled or water-cooled intercooler, may be provided in the line between consecutive pressure stages of the second refrigerant circuit, such as the low pressure and high pressure refrigerant compressors in any of the embodiments of Figures 3 to 5.

The invention can be applied on still other drive schemes as well. One typical modification, for instance, of the Split-MR drive scheme as shown in Figure 4 is that two pressure stages (e.g. LP and MP) are driven by the second gas turbine 220 on a single shaft 215, in which case of course the medium pressure compressor discharges to the second second compressor 211 (which functions as high pressure compressor). Likewise, multiple compressor stages can be driven on shaft 215 in Figure 5.

The invention described hereinabove is not limited to two refrigeration circuits: it can also be applied for dividing cooling duty of the chilled coolant over three or more parts for cooling third or more inlet air streams of other refrigerant circuits.

The embodiments described above contain another invention, which can be applied both in combination with the features associated with the dividing of cooling duty

available in the chilled coolant over at least first and second parts and the cooling of at least first and second gas turbine inlet air streams with the chilled coolant, and separately therefrom. The other invention can even
5 be applied in cooling and/or liquefaction processes based on a single refrigerant cycle. This other invention, which relates to a method of producing a liquefied hydrocarbon stream and an apparatus therefor, will be described in the remainder of the present specification.

10 Another drawback of the method described in US patent 6,324,867 to Exxon Mobil is that it uses cooling duty from a refrigerant circuit which cooling duty is therefore not available to cool the natural gas that is to be liquefied.

15 In one aspect, the other invention described herein may be defined as providing a method of producing a liquefied hydrocarbon stream, comprising:

- indirect heat exchanging a hydrocarbon stream in one or more heat exchangers against one or more refrigerants
20 from one or more refrigerant circuits, at least one of which refrigerant circuits comprising a compressor driven by a gas turbine by which compressor the refrigerant of that refrigerant circuit is compressed;

- withdrawing a fraction from the hydrocarbon stream
25 after it has been heat exchanged in at least one of the one or more heat exchangers;

- providing a stream of a chilled coolant by indirect heat exchanging the chilled coolant against at least a part of the withdrawn fraction of the hydrocarbon stream;

30 - chilling an inlet air stream comprising heat exchanging with the chilled coolant to produce a chilled inlet air stream, and feeding the chilled inlet air stream to the gas turbine;

wherein the produced liquefied hydrocarbon stream comprises at least part of the hydrocarbon stream that has not been withdrawn.

Thus, in embodiments of the other invention, a
5 fraction is withdrawn from the hydrocarbon stream after it has been heat exchanged in at least one of one or more heat exchangers, thus suitably downstream of at least one of one or more heat exchangers, to provide a stream of a chilled coolant that, in turn, is used to produce a
10 chilled inlet air stream at least by heat exchanging the chilled coolant with the inlet air stream. The chilled inlet air stream to the gas turbine that drives a refrigerant circuit employed for cooling a hydrocarbon stream in the one or more heat exchangers, and producing
15 a liquefied hydrocarbon stream therefrom.

Such fractions of hydrocarbon stream are often removed from the hydrocarbon stream to be liquefied anyway, for various uses or reasons. Since the fraction is removed downstream of at least one of the one or more
20 heat exchangers, it has the ability to chill the inlet air stream before its other use or before being discarded.

Any cooling duty that can be provided from the removed fraction for the purpose of gas turbine inlet air
25 chilling, does not need to be removed from a refrigerant cycle that is intended to cool the hydrocarbon stream to be liquefied. This way, the invention helps to further increase the production rate of the liquefied hydrocarbon without a need to install additional refrigeration power.

30 Examples of removed fractions that can be employed for chilling the inlet air stream of a gas turbine include:

- a natural gas liquids stream that has been extracted from the hydrocarbon stream in order to meet a composition specification for the liquefied hydrocarbon stream;

5 - a fuel gas stream removed from the hydrocarbon stream for the purpose of being combusted, for instance in one or more of the gas turbines;

- an end flash stream created upon depressurizing a pressurized liquefied hydrocarbon stream;

10 - a boil-off gas stream originating from the liquefied hydrocarbon stream during its storage in a storage tank.

Again, in the context of the other invention, the term "chilled coolant" is understood to be a fluid that
15 has a temperature lower than that of the ambient air temperature. But in this case, the chilled coolant can be prepared by actively chilling the fluid, using refrigeration duty from any cold stream available in the hydrocarbon liquefaction process that is not cycled in a
20 refrigerant circuit.

Favorable examples include the liquid bottom stream of an extraction column and/or a fractionation column and/or an overhead stream from a fractionation column, a stream of end-flash gas that may be generated when
25 letting down the pressure of the liquefied hydrocarbon stream, a stream of boil-off gas that may be evaporated off of the liquefied hydrocarbon while in storage.

The cooling duty available in one or more of these removed fractions may be supplemented by cooling duty
30 obtained from a refrigerant cycled in a refrigerant circuit. Examples include mechanical chilling or absorption chilling. The cooling duty may for instance be supplemented using an external chilling package.

The indirect heat exchanging of the hydrocarbon stream in one or more heat exchangers against one or more refrigerants from one or more refrigerant circuits may comprise:

- 5 - cooling the hydrocarbon stream by heat exchanging against a first refrigerant from a first refrigerant circuit in which said first refrigerant is compressed in a first compressor driven by a first gas turbine having a first inlet air stream, said cooling providing a cooled hydrocarbon stream;
- 10 - liquefying at least part of the cooled hydrocarbon stream using a second refrigerant, which second refrigerant is compressed in a second compressor driven by a second gas turbine having a second inlet air stream, and cooled at least by heat exchanging with said first refrigerant from the first refrigerant circuit, said liquefying providing a liquefied hydrocarbon stream;
- 15 wherein said chilling of said inlet air stream comprises cooling one or both of said first and second inlet air streams with at least a part of the chilled coolant.
- 20

These features have been amply described in the preceding parts of the specification. It also follows from the preceding parts of the specification that advantages embodiments may further comprise:

- 25 - dividing the cooling duty available in the chilled coolant over at least first and second parts, whereby the cooling duty available in the first part is used to cool the first inlet air stream, and the cooling duty available in the second part is used to cool the second inlet air stream. Said cooling duty may be divided in accordance with the common input parameter as set forth in the preceding parts of the specification, preferably to divide the cooling duty available in the chilled
- 30

coolant such as to provide relatively more chilling duty to the inlet air stream of the gas turbine that drives the most constraining refrigerant circuit of the first and second refrigerant circuits.

5 However, it should be stressed that the other invention now being described is not limited to two refrigeration circuits. It can for instance also be applied for dividing cooling duty of the chilled coolant over three or more parts for cooling third or more inlet
10 air streams of other refrigerant circuits. And the other invention is also useful in liquefaction processes that use only one refrigeration circuit, typically consisting of so-called single mixed refrigerant processes. Amongst others, an example is formed by the Shell single mixed
15 refrigerant process described in U.S. Patent 5,832,745.

Said withdrawing of the fraction from the hydrocarbon stream after it has been heat exchanged in at least one of the one or more heat exchangers may comprise:

- producing a partially condensed hydrocarbon stream from
20 the gaseous hydrocarbon stream;
- passing the partially condensed hydrocarbon stream through a gas/liquid phase separator; and
- drawing a liquid bottom stream and a vaporous overhead stream from the gas/liquid phase separator. In such
25 embodiments, said fraction from the hydrocarbon stream may advantageously comprises the liquid bottom stream and said liquefied hydrocarbon stream is produced from the vaporous overhead stream. Alternatively or in addition thereto, such embodiments may comprise drawing off a fuel
30 gas stream from the vaporous overhead stream and wherein said fraction from the hydrocarbon stream comprises the fuel gas stream.

Said withdrawing of the fraction from the hydrocarbon stream after it has been heat exchanged in at least one of the one or more heat exchangers may also, or instead, comprise:

- 5 - obtaining at least an intermediate liquefied hydrocarbon stream out of the hydrocarbon stream;
- depressurizing the intermediate liquefied hydrocarbon stream;
- passing the depressurized stream into a phase
10 separator;
- separating any vaporous constituents from any liquid hydrocarbons in the depressurized stream;
- removing the liquid hydrocarbons from the phase
15 separator as the produced liquefied hydrocarbon product stream;
- removing the vaporous constituents from the phase separator,

wherein said fraction from the hydrocarbon stream comprises the vaporous constituents withdrawn from the
20 phase separator.

Said withdrawing of the fraction from the hydrocarbon stream after it has been heat exchanged in at least one of the one or more heat exchangers may also, or instead, comprise:

- 25 - storing the produced liquefied hydrocarbon stream in a storage tank; and
- withdrawing boil off gas, originating from the liquefied hydrocarbon stream being stored, from the storage tank,

wherein said fraction from the hydrocarbon stream
30 comprises the boil off gas.

In another aspect, the other invention may be defined as providing an apparatus for producing a liquefied hydrocarbon stream, comprising:

- one or more refrigerant circuits each comprising a refrigerant, at least one of which refrigerant circuits comprising a compressor driven by a gas turbine, for compressing the refrigerant of that refrigerant circuit;

- an inlet air stream to the gas turbine;

- one or more heat exchangers for indirectly heat exchanging a hydrocarbon stream against one or more refrigerants from the one or more refrigerant circuits, including said at least one;

- withdrawing means for withdrawing a fraction of the hydrocarbon stream downstream of at least one of the one or more heat exchangers and providing a remaining hydrocarbon stream from which the fraction has been withdrawn;

- a chiller connected to the withdrawing means and arranged to receive at least part of the withdrawn fraction from the withdrawing means, and further arranged to indirectly heat exchange a coolant fluid against the at least part of the withdrawn fraction to produce a stream of a chilled coolant from the coolant fluid

- an inlet air cooling heat exchanger arranged in the inlet air stream to cool the inlet air stream with the chilled coolant;

- a feed duct to feed the cooled inlet air stream from the inlet air cooling heat exchanger into the gas turbine;

- conduit means for conveying a liquefied hydrocarbon stream that comprises at least part of the remaining hydrocarbon stream.

As in embodiments described in the preceding parts of the specification, the one or more refrigerant circuits may comprise:

- a first refrigerant circuit comprising a first refrigerant, a first compressor, a first gas turbine coupled to the first compressor to drive the first compressor, and a first inlet air stream to the first gas turbine; the first compressor arranged to compress said first refrigerant;

- a second refrigerant circuit comprising a second refrigerant, a second compressor, a second gas turbine coupled to the second compressor to drive the second compressor, and a second inlet air stream to the second gas turbine; the second compressor arranged to compress said second refrigerant;

and wherein the one or more heat exchangers comprise:

- one or more first heat exchangers arranged to receive and cool the gaseous hydrocarbon stream and the second refrigerant, using said first refrigerant from said cooling providing a cooled hydrocarbon stream and a cooled second refrigerant stream;

- one or more second heat exchangers arranged to receive and liquefy the cooled hydrocarbon stream using the cooled second refrigerant stream, so as to provide the liquefied hydrocarbon stream;

and wherein the inlet air cooling heat exchanger is arranged in at least one of the first and the second inlet air streams.

Such embodiments may further comprise:

- a divider to divide the chilled coolant over at least first and second parts in accordance with a common input parameter;

wherein the inlet air cooling heat exchanger comprises:

- a first inlet air cooling heat exchanger arranged in the first inlet air stream to cool the first inlet air stream with the first part of the chilled coolant;
- a second inlet air cooling heat exchanger arranged in the second inlet air stream to cool the second inlet air stream with the second part of the chilled coolant.

In preferred embodiments, the withdrawing means may comprise a gas/liquid separator having an overhead outlet for discharging a vaporous overhead stream and a bottom outlet for discharging a liquid bottom stream. In such embodiments, said fraction of the hydrocarbon stream may advantageously comprise the liquid bottom stream and said remaining stream comprises the vaporous overhead stream. Alternatively or in addition thereto, such embodiments may further comprise a splitter in the vaporous overhead stream for drawing off a fuel gas stream from the vaporous overhead stream and wherein said fraction of the hydrocarbon stream comprises the fuel gas stream.

Alternatively or in addition thereto, the withdrawing means may comprise:

- depressurizing equipment arranged to receive an intermediate liquefied hydrocarbon stream formed out of the hydrocarbon stream and to form a depressurized stream therefrom;
- phase separation equipment arranged downstream of the depressurizing equipment to receive the depressurized stream and to separate any vaporous constituents from any liquid hydrocarbons in the depressurized stream;
- a liquid discharge line connected to the phase separation equipment for removing liquid hydrocarbons from the phase separator as the produced liquefied hydrocarbon product stream;

- a vapour discharge line connected to the phase separation equipment withdrawing the vaporous constituents from the phase separator, wherein said fraction from the hydrocarbon stream comprises the vaporous constituents removed from the phase separator.

The apparatus may comprise a storage tank for storing the produced liquefied hydrocarbon stream. In such a case, the withdrawing means may comprise:

- a boil-off gas conduit connected to the storage tank for withdrawing boil-off gas, originating from the liquefied hydrocarbon stream being stored, from the storage tank. In such embodiments, said fraction from the hydrocarbon stream may comprise the boil off gas.

The other invention will now be further illustrated in more detail by way of example and with reference to figures in the accompanying drawing.

Referring to Figure 1, a liquefied hydrocarbon stream 20 is produced by indirect heat exchanging a hydrocarbon stream 10 in one or more heat exchangers 140 (and/or 260) against one or more refrigerants from one or more refrigerant circuits 100 (and/or 200). At least one of these refrigerant circuits comprises a compressor 110 (and/or 210) driven by a gas turbine 120 (and/or 220) by which compressor the refrigerant of that refrigerant circuit is compressed. A fraction 70 (and/or 62 and/or 92) is withdrawn from the hydrocarbon stream after it has been heat exchanged in at least one of the one or more heat exchangers and a stream of a chilled coolant 320 is provided by indirect heat exchanging the coolant 315 against at least a part CF of the withdrawn fraction of the hydrocarbon stream. An inlet air stream 125 (and/or 225) is chilled with the chilled coolant 320 to produce a

chilled inlet air stream, which is fed to the gas turbine. The produced liquefied hydrocarbon stream 20 comprises at least part of the hydrocarbon stream that has not been withdrawn.

5 It is herewith proposed to use refrigeration duty provided by any cold stream available in the process that is not circulated in a refrigerant circuit. More specifically, the refrigeration duty may be provided by a fraction withdrawn from the hydrocarbon stream after it
10 has been heat exchanged in at least one of the one or more heat exchangers, thus suitably downstream of at least one of the one or more heat exchangers. Suitably, the fraction is subsequently discarded from the process or subsequently used in the process in a way that it
15 needed to be warmer. In both these cases, the cold in the fraction is favourably used to chill inlet air and thereby increase the LNG production.

For instance, referring to Figure 1, if gas/liquid phase separator 50 is present it may be comprised in the
20 withdrawing means, in which case the cold fluid CF may for instance be derived from or contain the liquid bottom stream 70. In this case, optional heat exchanger 73 may be in communication with stream 320 or the optional heat exchanger 73 may be one of the one or more chillers 325.

25 Still referring to Figure 1, other examples of cold streams that may be used to provide part of or all of the refrigeration duty for the active cooling of the coolant include fuel gas stream 62, end flash stream 92, and any cold stream from (optional) fractionation train 75.

30 Figure 1 shows symbolically optional chillers 61 and 91 that could be used as chiller(s) 325 or be otherwise positioned in communication with line 320. Boil off gas, for instance from a storage tank wherein the liquefied

hydrocarbon stream 20 may be stored, may also be used to provide part of or all of the refrigeration duty for the active cooling of the coolant.

5 In addition to any one of these streams mentioned above, other sources chilling duty provided may be employed for the inlet air chilling, including any refrigerant cycled in a refrigerant circuit and undergoing compression and expansion in the circuit (as known in the art) or a refrigerant cycled in a thermally
10 driven chilling process. Reference is made to the earlier description of Figure 1 for further details.

The alternative drive schemes as illustrated in Figures 3 to 5 can also be applied with the other invention now being described.

15 The person skilled in the art will understand that each of the present inventions can be carried out in many various ways without departing from the scope of the appended claims.

C L A I M S

1. Method of cooling a gaseous hydrocarbon stream to produce a liquefied hydrocarbon stream, comprising:

- cooling the gaseous hydrocarbon stream in one or more heat exchangers using a first refrigerant from a first refrigerant circuit in which said first refrigerant is compressed in a first compressor driven by a first gas turbine having a first inlet air stream, said cooling providing a cooled hydrocarbon stream;

- liquefying the cooled hydrocarbon stream using a second refrigerant, which second refrigerant is compressed in a second compressor driven by a second gas turbine having a second inlet air stream, and cooled at least by heat exchanging with said first refrigerant from the first refrigerant circuit, said liquefying providing a liquefied hydrocarbon stream;

- providing a stream of a chilled coolant;

- dividing the cooling duty available in the chilled coolant over at least first and second parts in accordance with a common input parameter;

- cooling one or both of said first and second inlet air streams with the chilled coolant, whereby the cooling duty available in the first part is used to cool the first inlet air stream, and the cooling duty available in the second part is used to cool the second inlet air stream.

2. The method of claim 1, wherein the common input parameter is used to divide the cooling duty available in the chilled coolant such as to provide relatively more chilling duty to the inlet air stream of the gas turbine

that drives the most constraining refrigerant circuit of the first and second refrigerant circuits.

3. The method of claim 1 or 2, wherein the common input

parameter includes one or more parameters indicative of

at least one the group consisting of: ambient

temperature; first compressor discharge pressure; first

gas turbine load/poweroutput; second gas turbine

load/poweroutput; first gas turbine fuel gas valve

opening; second gas turbine fuel gas valve opening; cut

point temperature between first and second refrigerant

cycle; first compressor adsorbed power; second compressor

absorbed power; difference between first and second gas

turbine power output; flow rate of liquefied hydrocarbon

stream.

4. The method of claim 1 or 2, wherein the common input

parameter includes one or more parameter indicative of at

least ambient temperature.

5. The method of any one of the preceding claims,

wherein said providing of the stream of the chilled

coolant comprises chilling a fluid.

6. The method of claim 5, wherein the fluid is actively

chilled using refrigeration duty taken from one or more

of the first and second refrigerant circuits.

7. The method of claim 5, wherein the fluid is actively

chilled using refrigeration duty taken from the first

refrigerant circuit.

8. The method of any one of claims 5 to 7, wherein said

providing of the cooled hydrocarbon stream comprises

producing a partially condensed hydrocarbon stream from

the gaseous hydrocarbon stream and passing the partially

condensed hydrocarbon stream through a gas/liquid phase

separator and drawing a liquid bottom stream and a

vaporous overhead stream from the gas/liquid phase

separator, and wherein the fluid is actively chilled using refrigeration duty taken from the liquid bottom stream.

9. The method of any one of claims 5 to 8, wherein the fluid comprises the chilled coolant after it has been used for said cooling of the one or both of said first and second inlet air streams.

10. The method of any one of the preceding claims, dividing the cooling duty available in the chilled coolant over at least first and second parts in accordance with a common input parameter comprises determining an optimum division of the cooling duty available in the chilled refrigerant over the first and second parts based on the common input parameter and dividing the cooling duty in accordance with the determined optimum division.

11. The method of claim 10, wherein the optimum division is the division whereby the liquefied hydrocarbon stream production rate is maximized.

12. The method of claim 10 or 11, wherein the optimum division is defined as the division whereby the first and second refrigerant circuits are equally constraining for maximising liquefied hydrocarbon production

13. Apparatus for cooling a gaseous hydrocarbon stream to produce a liquefied hydrocarbon stream, comprising:

- a first refrigerant circuit comprising a first refrigerant, a first compressor, a first gas turbine coupled to the first compressor to drive the first compressor, and a first inlet air stream to the first gas turbine; the first compressor arranged to compress said first refrigerant;
- a second refrigerant circuit comprising a second refrigerant, a second compressor, a second gas turbine

coupled to the second compressor to drive the second compressor, and a second inlet air stream to the second gas turbine; the second compressor arranged to compress said second refrigerant;

5 - one or more first heat exchangers arranged to receive and cool the gaseous hydrocarbon stream and the second refrigerant, using said first refrigerant from said cooling providing a cooled hydrocarbon stream and a cooled second refrigerant stream;

10 - one or more second heat exchangers arranged to receive and liquefy the cooled hydrocarbon stream using the cooled second refrigerant stream, so as to provide a liquefied hydrocarbon stream;

- a stream of a chilled coolant;

15 - a divider to divide the chilled coolant over at least first and second parts in accordance with a common input parameter;

- a first inlet air cooling heat exchanger arranged in the first inlet air stream to cool the first inlet air stream with the first part of the chilled coolant;

20 - a second inlet air cooling heat exchanger arranged in the second inlet air stream to cool the second inlet air stream with the second part of the chilled coolant.

14. The apparatus of claim 13, further comprising a controller arranged to receive a signal representative of the common input parameter, and to determine an optimum division of the cooling duty available in the chilled refrigerant over the first and second parts based on the common input parameter.

25 30 15. The apparatus of claim 14, wherein the optimum division is determined by which of the first and second refrigerant circuits is the most constraining of the two for maximising liquefied hydrocarbon production.

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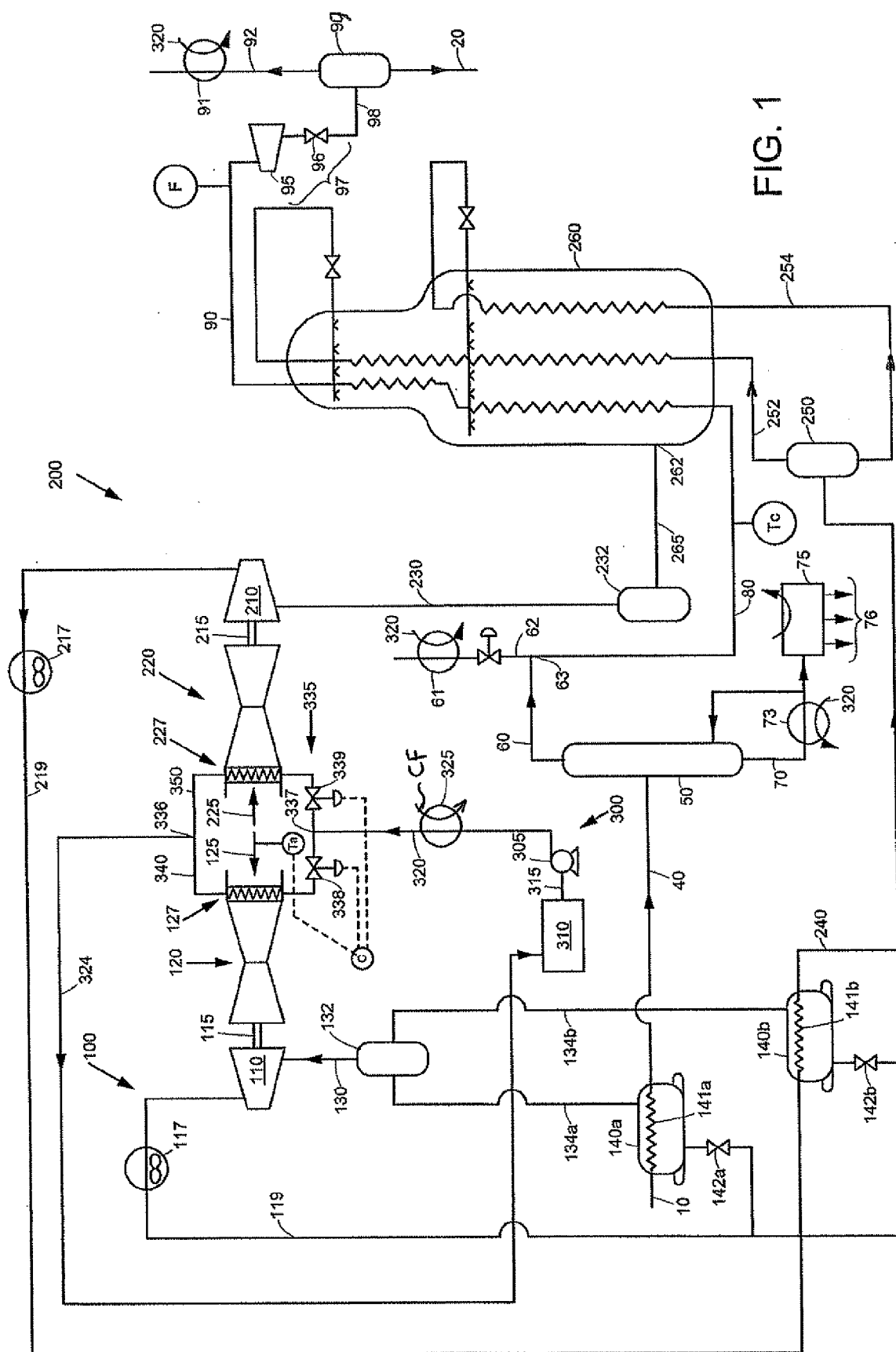


FIG. 1

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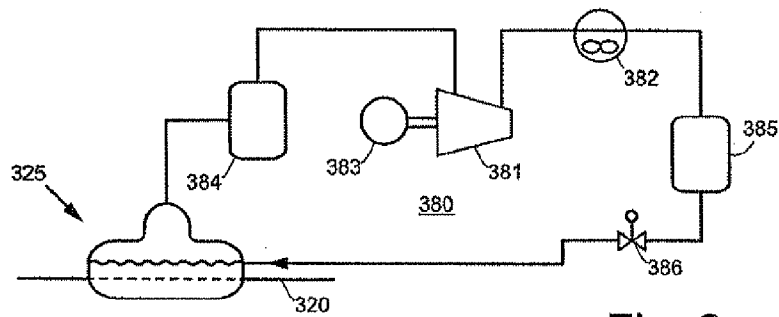


Fig. 2

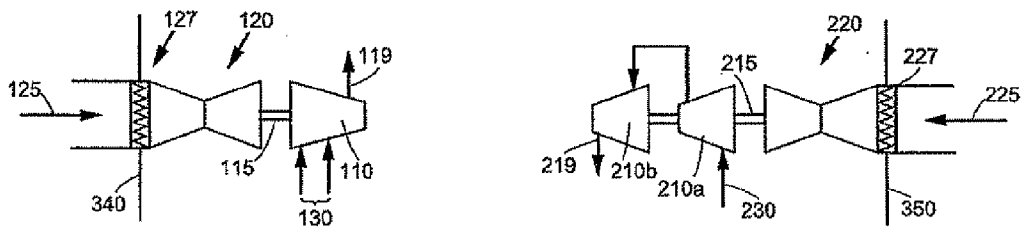


Fig. 3

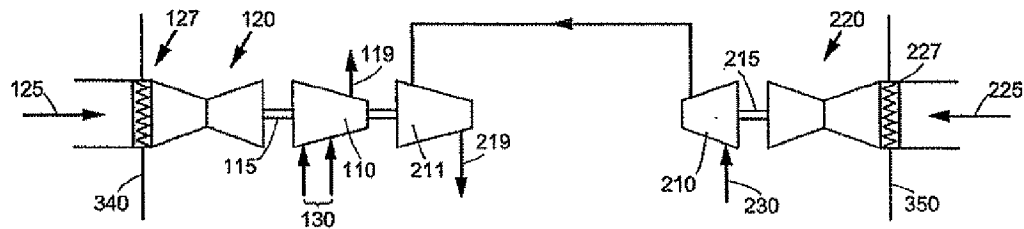


Fig. 4

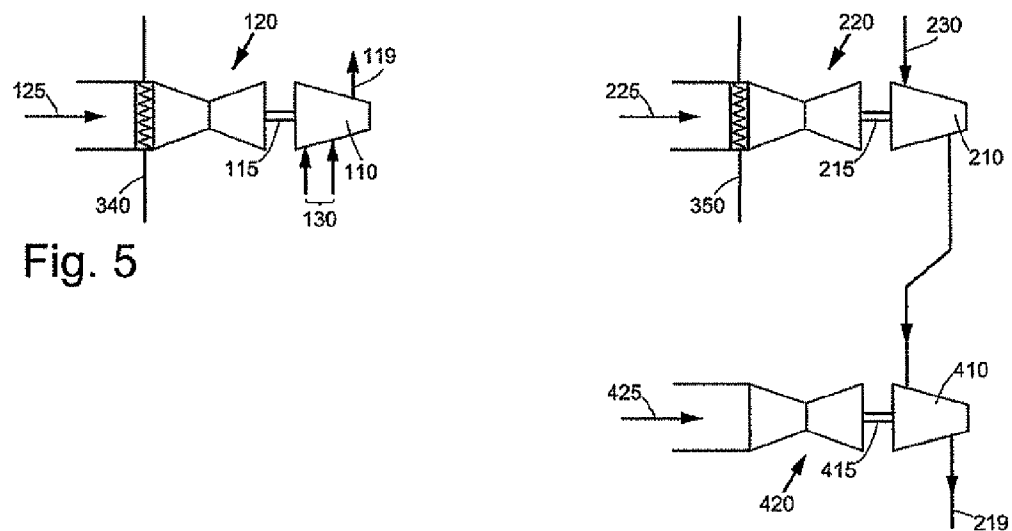


Fig. 5