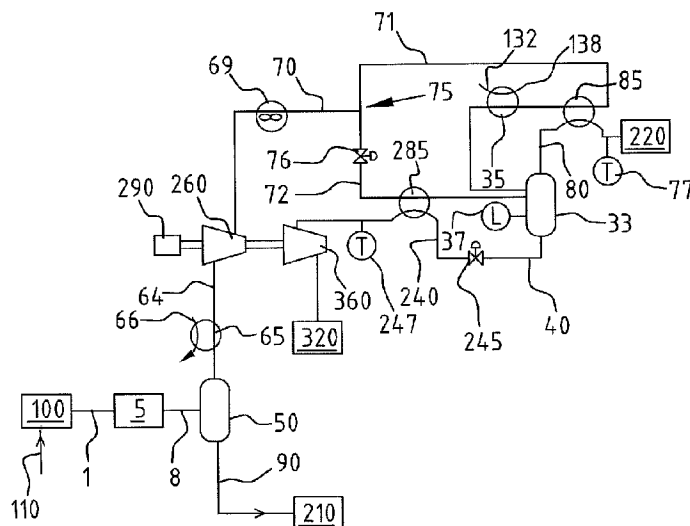




(86) Date de dépôt PCT/PCT Filing Date: 2014/03/25
(87) Date publication PCT/PCT Publication Date: 2014/10/30
(45) Date de délivrance/Issue Date: 2021/02/16
(85) Entrée phase nationale/National Entry: 2015/10/15
(86) N° demande PCT/PCT Application No.: EP 2014/055958
(87) N° publication PCT/PCT Publication No.: 2014/173597
(30) Priorités/Priorities: 2013/04/22 (EP13164694.5);
2013/04/22 (EP13164691.1); 2014/03/13 (EP14159503.3)

(51) Cl.Int./Int.Cl. *F25J 1/02* (2006.01),
F25J 1/00 (2006.01), *F25J 3/02* (2006.01)
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(54) Titre : PROCEDE ET APPAREIL DE PRODUCTION D'UN FLUX D'HYDROCARBURE LIQUEFIE
(54) Title: METHOD AND APPARATUS FOR PRODUCING A LIQUEFIED HYDROCARBON STREAM



(57) **Abrégé/Abstract:**

A cryogenic hydrocarbon composition, obtained by subjecting a raw liquefied hydrocarbon stream to a pressure reduction step, is first separated into a vaporous reject stream and a liquid stream. The liquid stream is discharged in the form of the liquefied hydrocarbon stream. The vaporous reject stream is recompressed, split into first and second compressed vapour part streams. Each part stream is indirectly heat exchanged whereby the first compressed vapour part stream is indirectly heat exchanged against the first auxiliary refrigerant stream and the second compressed vapour part stream against the second auxiliary refrigerant stream. The second auxiliary refrigerant stream is formed from the condensed fraction, which is thus revaporized and subsequently combusted in a gas turbine. The vapour fraction, which generally has a higher nitrogen content and a lower heating value than the condensed fraction, is combusted in a combustion device other than a gas turbine.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property
Organization
International Bureau



(10) International Publication Number
WO 2014/173597 A2

(43) International Publication Date
30 October 2014 (30.10.2014)

- (51) International Patent Classification: Not classified
- (21) International Application Number: PCT/EP2014/055958
- (22) International Filing Date: 25 March 2014 (25.03.2014)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
- | | | |
|------------|----------------------------|----|
| 13164691.1 | 22 April 2013 (22.04.2013) | EP |
| 13164694.5 | 22 April 2013 (22.04.2013) | EP |
| 14159503.3 | 13 March 2014 (13.03.2014) | EP |
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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))

[Continued on next page]

(54) Title: METHOD AND APPARATUS FOR PRODUCING A LIQUEFIED HYDROCARBON STREAM

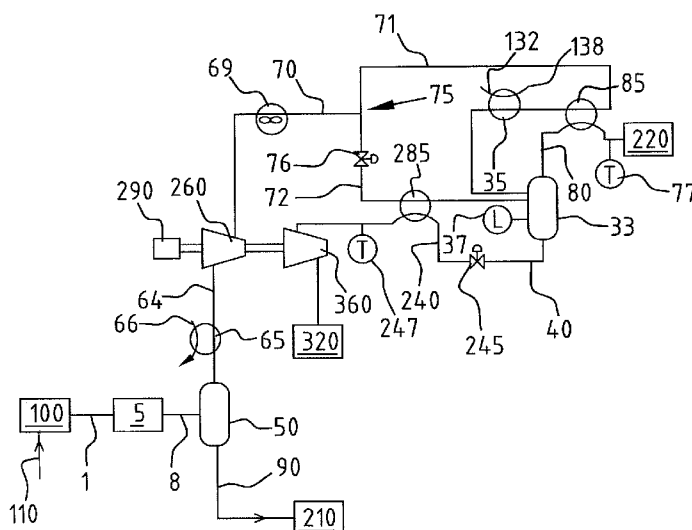


FIG. 1

(57) Abstract: A cryogenic hydrocarbon composition, obtained by subjecting a raw liquefied hydrocarbon stream to a pressure reduction step, is first separated into a vaporous reject stream and a liquid stream. The liquid stream is discharged in the form of the liquefied hydrocarbon stream. The vaporous reject stream is recompressed, split into first and second compressed vapour part streams. Each part stream is indirectly heat exchanged whereby the first compressed vapour part stream is indirectly heat exchanged against the first auxiliary refrigerant stream and the second compressed vapour part stream against the second auxiliary refrigerant stream. The second auxiliary refrigerant stream is formed from the condensed fraction, which is thus revaporized and subsequently combusted in a gas turbine. The vapour fraction, which generally has a higher nitrogen content and a lower heating value than the condensed fraction, is combusted in a combustion device other than a gas turbine.

WO 2014/173597 A2



Published:

- *without international search report and to be republished
upon receipt of that report (Rule 48.2(g))*

- 1 -

METHOD AND APPARATUS FOR PRODUCING A LIQUEFIED
HYDROCARBON STREAM

The present invention relates to a method and
apparatus for producing a liquefied hydrocarbon stream.

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

WO 2006/120127 describes an LNG separation process
and installation. Liquefied natural gas in liquid form
is sent to a separation unit, wherein a stream of LNG
purified of nitrogen, and a nitrogen-enriched vapour are
20 produced. The separation unit employs two columns. An
LNG stream which has been liquefied in a liquefier is
first separated in a first column operating at about 1.25
bar producing a nitrogen-depleted liquid and an overhead
gas stream. The overhead gas stream is recompressed to
25 about 4 bar and passed to a second column, where any
remaining methane is recondensed. The recondensed
methane is withdrawn as liquid from the second column and
mixed with the nitrogen-depleted liquid from the first
column to form the stream of LNG purified of nitrogen.
30 Gaseous nitrogen is withdrawn from the top of the second
column, allowing for the nitrogen contained in the
natural gas to be utilized at commercial purity.

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The refrigeration or said recondensing of the methane in the second column is provided by a nitrogen cycle independent of the liquefier, which employs a refrigerant fluid is of which the nitrogen content is greater than
5 80 mol%.

A drawback of this LNG separation process is that an independent refrigeration cycle is required which involves both capital expenditure as well as operational expenditure. Moreover, as the recondensed methane is
10 added to the purified LNG stream, it becomes increasingly demanding to maintain the nitrogen level in the purified LNG stream below the specification required for commercial LNG.

The present invention provides a method of producing
15 a liquefied hydrocarbon stream, comprising:

- providing a cryogenic hydrocarbon composition comprising a nitrogen- and methane-containing liquid phase at an initial pressure of between 1 and 2 bar absolute;
- 20 - phase separating the cryogenic hydrocarbon composition, in an end flash separator at a first separation pressure of between 1 and 2 bar absolute, into a vaporous reject stream and a liquid stream;
- discharging the liquid stream from the end flash
25 separator in the form of the liquefied hydrocarbon stream;
- compressing the vaporous reject stream in an end-flash compressor to a pressure of above 2 bar absolute, thereby obtaining a compressed vapour stream;
- 30 - splitting the compressed vapour into a first compressed vapour part stream and a second compressed vapour part stream whereby said first compressed vapour part stream

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- and second compressed vapour part stream both have the same composition and phase as the compressed vapour;
- forming a partially condensed intermediate stream comprising a condensed fraction and a vapour fraction,
- 5 comprising indirectly heat exchanging the first compressed vapour part stream against a first auxiliary refrigerant stream whereby passing heat from the first compressed vapour part stream to the first auxiliary refrigerant stream, and by indirectly heat exchanging the
- 10 second compressed vapour part stream against a second auxiliary refrigerant stream whereby passing heat from the second compressed vapour part stream to the second auxiliary refrigerant stream, and recombining both part streams;
- 15 - in a gas/liquid separator, separating the condensed fraction from the vapour fraction of the part streams after recombining, at a second separation pressure;
 - discharging the vapour fraction from the gas/liquid separator, said vapour fraction having a first heating
- 20 value;
- combusting the vapour fraction in a combustion device other than a gas turbine;
 - discharging the condensed fraction from the gas/liquid separator;
- 25 - revaporizing the condensed fraction whereby transforming the condensed fraction into a fully vaporized stream having a second heating value that is higher than the first heating value;
- combusting the fully vaporized stream in a gas
- 30 turbine;
- wherein said revaporizing of the condensed fraction comprises said indirectly heat exchanging of the second compressed vapour part stream by passing the condensed

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fraction through a pressure reduction valve thereby forming the second auxiliary refrigerant stream and subsequently subjecting said second auxiliary refrigerant stream to said indirectly heat exchanging against the second compressed vapour part stream whereby fully vaporizing the condensed fraction and wherein the first auxiliary refrigerant stream does not contain any of the condensed fraction.

In another aspect, the present invention provides an apparatus for producing a liquefied hydrocarbon stream, comprising:

- a cryogenic feed line connected to a source of a cryogenic hydrocarbon composition comprising nitrogen and a methane-containing liquid phase;
- an end-flash separator arranged to receive the cryogenic hydrocarbon composition and to separate the cryogenic hydrocarbon composition into a liquid stream and vaporous reject stream;
- a liquid hydrocarbon product line fluidly connected to a bottom part of the end-flash separator to discharge said liquid stream in the form of the liquefied hydrocarbon stream from the end-flash separator;
- a vapour reject line fluidly connected to an overhead part of the end-flash separator to discharge said vaporous reject stream from the end-flash separator;
- an end-flash compressor arranged in the vapour reject line to compress the vaporous reject stream, thereby obtaining a compressed vapour stream;
- a stream splitter configured in the compressed vapour line, for dividing the compressed vapour line over a first branch and a second branch, whereby the first branch is arranged between the stream splitter and the gas/liquid separator, and whereby the second branch is

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arranged between the stream splitter and the gas/liquid separator;

5 - a first auxiliary indirect heat exchanger arranged in the first branch, arranged to receive a first compressed vapour part stream available in the first branch and to establish indirect heat exchanging contact between the first compressed vapour part stream and a first auxiliary refrigerant stream;

10 - a second auxiliary indirect heat exchanger arranged in the second branch, arranged to receive a second compressed vapour part stream available in the second branch and to establish indirect heat exchanging contact between the second compressed vapour part stream and a second auxiliary refrigerant stream;

15 - a gas/liquid separator arranged downstream of both the first auxiliary heat exchanger and the second auxiliary heat exchanger, and arranged to receive a partially condensed intermediate stream from the first auxiliary heat exchanger and the second auxiliary heat exchanger, which partially condensed intermediate stream
20 comprises a condensed fraction and a vapour fraction;

- a vapour fraction discharge line fluidly connected with an overhead part of the gas/liquid separator arranged to receive the vapour fraction from the
25 gas/liquid separator;

- a combustion device other than a gas turbine fluidly connected with the gas/liquid separator by means of the vapour fraction discharge line to receive and combust the discharged vapour fraction;

30 - a condensed fraction discharge line fluidly connected with a bottom part of the gas/liquid separator arranged to receive the condensed fraction from the gas/liquid separator;

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- a gas turbine fluidly connected with the gas/liquid separator by means of the condensed fraction discharge line to receive and combust the discharged condensed fraction;
 - 5 - a revaporizer arranged in the condensed fraction discharge line between the gas/liquid separator and the gas turbine and arranged to transform the condensed fraction into a fully vaporized stream prior to combustion in the gas turbine;
 - 10 - a pressure reduction valve arranged in the condensed fraction discharge line between the gas/liquid separator and the revaporizer;
- wherein the second auxiliary heat exchanger is the revaporizer, wherein the condensed fraction downstream of the pressure reduction valve is the second auxiliary refrigerant stream, and wherein the first auxiliary refrigerant stream does not contain any of the condensed fraction.

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

Fig. 1 schematically represents a process flow scheme representing a method and apparatus for producing a liquefied hydrocarbon stream wherein the invention is incorporated;

Fig. 2 schematically represents an example of a pressure reduction system for use in the method and apparatus;

Fig. 3 schematically represents a process flow scheme representing a liquefier that may be used in the methods and apparatuses disclosed herein;

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Fig. 4 schematically represents a process flow scheme representing a method and apparatus according to a group of embodiments of the invention;

5 Fig. 5 schematically represents a process flow scheme representing a method and apparatus according to another group of embodiments of the invention;

Fig. 6 schematically represents a process flow scheme wherein the method and apparatus of Fig. 1 is applied with a different type of end-flash separator.

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

The present description concerns producing of a
15 liquefied hydrocarbon stream, such as for instance a liquefied natural gas stream. A cryogenic hydrocarbon composition is first separated into a vaporous reject stream and a liquid stream. The liquid stream is discharged in the form of the liquefied hydrocarbon
20 stream. After said discharging of the liquid stream from the end flash separator in the form of the liquefied hydrocarbon stream, the liquefied hydrocarbon stream may be conveyed to a cryogenic storage tank. Although not a mandatory requirement of the invention, the cryogenic
25 storage tank is preferably incorporated within a hull of a floatable barge.

The vaporous reject stream is recompressed and split into a first compressed vapour part stream and a second compressed vapour part stream. The first compressed
30 vapour part stream and second compressed vapour part stream both have the same composition and phase as the compressed vapour. Then a partially condensed intermediate stream is formed, comprising a condensed

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fraction and a vapour fraction, whereby indirectly heat exchanging the first compressed vapour part stream against a first auxiliary refrigerant stream and indirectly heat exchanging the second compressed vapour part stream against a second auxiliary refrigerant stream. After having thus been subjected to indirect heat exchanging, both part streams are recombined and separated at a second separation pressure in a gas/liquid separator, whereby the condensed fraction is separated from the vapour fraction of the part streams after recombining.

The condensed fraction is revaporized and combusted in a gas turbine. This fuel gas vapour stream is identified as high quality fuel gas stream. Revaporizing of the condensed fraction comprises said indirectly heat exchanging of the second compressed vapour part stream by passing the condensed fraction through a pressure reduction valve thereby forming the second auxiliary refrigerant stream and subsequently subjecting said second auxiliary refrigerant stream to said indirectly heat exchanging against the second compressed vapour part stream whereby fully vaporizing the condensed fraction and wherein the first auxiliary refrigerant stream does not contain any of the condensed fraction.

The vapour fraction, which generally has a higher nitrogen content and a lower heating value than the condensed fraction, is combusted in a combustion device other than a gas turbine. In the context of the present description and compared to the condensed fraction, this fuel is referred to as low quality fuel gas. Low quality in this context means having a heating value that is lower compared to the heating value of the high quality

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fuel gas vapour stream, which is combusted in the gas turbine.

5 The advantage of splitting the compressed vapour in the part streams is that the cold from the condensed fraction which is transformed into a fully vaporized stream with the higher heating value to be combusted in the gas turbine can be used over the entire temperature range, as the second auxiliary refrigerant, to form the partially condensed intermediate stream. This way the amount of cooling duty needed from the first auxiliary
10 refrigerant stream is reduced.

No high degree of separation between the methane and the nitrogen in the intermediate condensed stream formed from the vaporous reject stream is required, as both the vapour fraction and the condensed fraction are combusted.
15 Therefore the vapour fraction does not have to be free from methane while the condensed fraction is bound to less stringent requirements for its nitrogen content than if it would be added to the liquefied hydrocarbon stream.

20 The proposed method and apparatus thus do not require a full nitrogen rejection unit, since a combustible fuel gas stream is produced instead of a ventable nitrogen stream.

The cryogenic hydrocarbon composition may be obtained
25 by subjecting a raw liquefied hydrocarbon stream to a pressure reduction step.

The cryogenic hydrocarbon composition may be sourced from a liquefier. Such liquefier may comprise a refrigerant circuit for cycling a refrigerant stream.
30 The refrigerant circuit may comprise a refrigerant compressor coupled to a refrigerant compressor driver, and arranged to compress the refrigerant stream; and a cryogenic heat exchanger arranged to establish an

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indirect heat exchanging contact between a hydrocarbon stream and the refrigerant stream of the refrigerant circuit, whereby a raw liquefied stream is formed out of the hydrocarbon stream comprising a subcooled hydrocarbon stream. The liquefier may further comprise a pressure reduction system arranged downstream of the cryogenic heat exchanger and in fluid communication therewith, to receive the raw liquefied stream and to reduce pressure of the raw liquefied stream. A rundown line may fluidly connect the pressure reduction system with the cryogenic heat exchanger to establish fluid communication for the raw liquefied stream to pass from the cryogenic heat exchanger to the pressure reduction system, wherein the end-flash separator is arranged downstream of the pressure reduction system and in fluid communication therewith to receive the cryogenic hydrocarbon composition from the pressure reduction system. Suitably, the gas turbine in which the condensed fraction is revaporized and combusted is the refrigerant compressor driver of the refrigerant circuit in the liquefier. The gas turbine is preferably selected from the group consisting of aeroderivative gas turbines.

Accordingly, the method may suitably comprise cycling a refrigerant stream in the liquefier, comprising driving a refrigerant compressor and compressing said refrigerant stream in the refrigerant compressor. A hydrocarbon stream may be condensed and subcooled, comprising indirectly heat exchanging said hydrocarbon stream against the refrigerant stream in the liquefier, thereby forming a raw liquefied stream at a liquefaction pressure of higher than 2 bara. The raw liquefied stream may be passed through a pressure reduction step, thereby obtaining the cryogenic hydrocarbon composition

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comprising nitrogen and a methane-containing liquid phase. Suitably, the refrigerant compressor is driven by the mentioned gas turbine in which the fully vaporized condensed fraction is combusted.

5 The first auxiliary refrigerant stream may advantageously be formed by a slip stream of the liquefied hydrocarbon stream or a by slip stream of a cycled refrigerant stream from the liquefier whereby the cryogenic hydrocarbon composition is produced by
10 condensing and subcooling a hydrocarbon stream comprising heat indirectly exchanging the hydrocarbon stream against the cycled refrigerant stream in the liquefier.

 The proposed method and apparatus can be advantageously applied for instance if the raw liquefied
15 stream comprises in the range of from 1 mol% to 7 mol% nitrogen. However, most benefit is enjoyed in cases wherein the raw liquefied stream comprises more than 3 mol% of nitrogen, as in such cases a relatively high flow rate of vaporous reject gas is generated in order to
20 maintain the liquid stream from which the liquefied hydrocarbon stream is derived within specification with regard to maximum content of lower boiling constituents such as nitrogen in commercially tradable liquefied natural gas. The high flow rate of vaporous reject gas
25 generally contains too much nitrogen for use as fuel in gas turbines, and it usually exceeds plant fuel requirements if gas turbines are used to drive the refrigeration cycles in the liquefier.

 More than 30 mol% of the vaporous reject stream
30 and/or more than 30 mol% of the partially condensed intermediate stream may consist of nitrogen. Such nitrogen content would be too high to meet the fuel gas requirements of most gas turbines. The proposed method

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and apparatus may then be advantageously employed to
recondense a fraction of the vaporous reject stream, to
obtain a condensed fraction of which less than 30 mol%
consists of nitrogen so that, after revaporization, it
5 can be used to fuel a gas turbine.

If the nitrogen content is still too high for the
selected gas turbine, the condensed fraction (preferably
after revaporization) may be blended with other fuel gas
to bring the fuel on specification. In such cases the
10 invention provides the benefit that the blending
requirements are less demanding than if the fuel gas had
more than 30 mol% of nitrogen.

The revaporized condensed fraction may have to be
subjected to compression in order to meet a pre-
15 determined gas turbine fuel gas pressure specification.

Figure 1 illustrates embodiments of the invention. A
cryogenic hydrocarbon composition comprising a nitrogen-
and methane-containing liquid phase is conveyed in a
cryogenic feed line 8. The source of the cryogenic
20 hydrocarbon composition is not a limitation of the
invention in its broadest definition, but for the sake of
completeness one embodiment is illustrated wherein the
cryogenic hydrocarbon composition is sourced from a
liquefier 100 which transforms a hydrocarbon stream 110
25 into a raw liquefied stream.

Such a liquefier 100 would typically be provided
upstream of the cryogenic feed line 8. The liquefier 100
may be in fluid communication with the cryogenic feed
line 8 via a pressure reduction system 5, which
30 communicates with the liquefier 100 via a rundown line 1.
The pressure reduction system 5 is arranged downstream of
the cryogenic heat exchanger 180 and arranged to receive

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and reduce the pressure of a raw liquefied stream from the main cryogenic heat exchanger 5.

The pressure reduction system 5 may comprise a dynamic unit, such as an expander turbine, a static unit, such as a Joule Thomson valve, or a combination thereof. An example of a pressure reduction system 5 with a Joule Thomson valve 7 in series with an expander turbine 6 is shown in Fig. 2. If an expander turbine is used, it may optionally be drivingly connected to a power generator. Many arrangements are possible and known to the person skilled in the art.

An end-flash separator 50 is arranged to receive the cryogenic hydrocarbon composition 8, optionally downstream of the pressure reduction system 5 and in fluid communication therewith, if such system is provided. Depending on the separation requirements, the end flash separator 50 may be provided in the form of a simple drum which separates vapour from liquid phases in a single equilibrium stage (such as depicted in Fig. 1), or a more sophisticated distillation column. Non-limiting examples of possibilities are disclosed in US Patents 5,421,165; 5,893,274; 6,014,869; 6,105,391; and pre-grant publication US 2008/0066492. A specific example will be illustrated below, with reference to Fig. 6

A liquid hydrocarbon product line 90 is fluidly connected to a bottom part of the end-flash separator 50. The liquid hydrocarbon product line 90 connects the end-flash separator 50 to a cryogenic storage tank 210. An optional cryogenic pump (not shown) may be present in the liquid hydrocarbon product line 90, to assist the transport of any liquid hydrocarbon product that is being discharged from the end-flash separator 50 to the

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cryogenic storage tank 210. The cryogenic storage tank 210 is preferably incorporated within a hull of a floatable barge.

5 A vapour reject line 64 is fluidly connected to an overhead part of the end-flash separator 50. An end-flash compressor 260 is arranged in the vapour reject line 64, to compress the vaporious reject stream from the end-flash separator 50. The end flash compressor 260 discharges into a compressed vapour stream line 70.

10 A stream splitter 75 is provided in the compressed vapour stream line 70, whereby the compressed vapour stream line 70 is divided over a first branch 71 and a second branch 72. The first branch 71 is arranged to convey a first compressed vapour part stream to a
15 gas/liquid separator 33, and the second branch 72 is arranged to convey a second compressed vapour part stream to the same gas/liquid separator 33. The stream splitter 75 merely divides the incoming compressed vapour stream 70 into two part streams of equal composition and phase.
20 The stream splitter 75 may be a pipe junction in the form a simple T-junction, preferably in conjunction with a split ratio control valve 76 in one of the first and second branches.

25 An aftercooler 69 may be provided in the compressed vapour stream line 70 between the end-flash compressor 260 and the stream splitter 75. The aftercooler is arranged to reject heat from the compressed vapour to the ambient (for instance by heat exchanging against an ambient air stream or an ambient water stream). Such an
30 aftercooler is recommended in embodiments where the temperature of the compressed vapour stream as it is discharged from the end-flash compressor exceeds the temperature of the ambient air and/or ambient water so

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that at least part of the heat added to the vapour in the end-flash compressor can be rejected to the ambient.

5 A first auxiliary indirect heat exchanger 35 is arranged in the first branch 71, downstream of the end-flash compressor 260 and the stream splitter 75. A second auxiliary indirect heat exchanger 285 is arranged in the second branch 72. The first auxiliary indirect heat exchanger 35 may be a condenser wherein the first compressed vapour part stream is at least partially
10 condensed.

The first auxiliary indirect heat exchanger 35 is arranged to receive the first compressed vapour part stream in the first branch 71, and to form a partially condensed intermediate stream from the first compressed
15 vapour part stream. The first auxiliary indirect heat exchanger 35 is arranged to establish indirect heat exchanging contact between at least the first compressed vapour part stream, and a first auxiliary refrigerant stream 132.

20 A gas/liquid separator 33 is arranged downstream of the first auxiliary indirect heat exchanger 35 and downstream of the second auxiliary indirect heat exchanger 285. A vapour fraction discharge line 80 is fluidly connected with an overhead part of the gas/liquid separator 33 and a condensed fraction discharge line 40
25 is fluidly connected with a bottom part of the gas/liquid separator 33.

A combustion device 220 other than a gas turbine is fluidly connected with the gas/liquid separator by means
30 of the vapour fraction discharge line 80. The combustion device 220 may comprise multiple combustion units. It may include, for example, one or more of a furnace, a boiler, an incinerator, a dual fuel diesel engine, or

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cross-combinations thereof. A boiler and a duel fuel diesel engine may advantageously be coupled to an electric power generator.

5 A gas turbine 320 is fluidly connected with the gas/liquid separator, by means of the condensed fraction discharge line 40. The second auxiliary indirect heat exchanger 285 is arranged in the condensed fraction discharge line 40, between the gas/liquid separator 33 and the gas turbine 320, with the aim to be a revaporizer
10 for the condensed fraction. The second auxiliary indirect heat exchanger 285 is arranged to bring the condensed fraction in the condensed fraction discharge line 40 in indirect heat exchanging contact with the second compressed vapour part stream in the second branch
15 72, whereby during operation heat is transferred from the second compressed vapour part stream to the condensed fraction in the condensed fraction discharge line 40. Thus, the second compressed vapour part stream is employed as heating fluid for the second auxiliary
20 indirect heat exchanger 285. A pressure reduction valve 245 is arranged in the condensed fraction discharge line 40 between the gas/liquid separator 33 and the second auxiliary indirect heat exchanger 285. Optionally, a fuel gas compressor 360 is arranged in the condensed
25 fraction discharge line 40 between the second auxiliary indirect heat exchanger 285 and the gas turbine 320.

A cold recovery heat exchanger 85 may optionally be provided in the vapour fraction discharge line 80 to recover cold vested in the vapour fraction prior to
30 combusting it in the combustion device 220. The cold recovery heat exchanger 85 is arranged to bring the vapour fraction in the vapour fraction discharge line 80 in indirect heat exchanging contact with the first

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compressed vapour part stream which acts as the cold recovery stream. Advantageously, the optional cold recovery heat exchanger 85 is arranged in the first branch 71, between the stream splitter 75 and the first auxiliary indirect heat exchanger 35, such that the first compressed vapour part stream is employed as cold recovery fluid. During operation heat is transferred from the first compressed vapour part stream in the first branch 71 to the vapour fraction in the vapour fraction discharge line 80. This cold recovery heat exchanger 85 may be referred to as first cold recovery heat exchanger in embodiments wherein a cold recovery heat exchanger 65 is provided in the vapour reject line 64. In such embodiments, the cold recovery heat exchanger 65 in the vapour reject line 64 may be referred to as second cold recovery heat exchanger.

Such optional cold recovery heat exchanger 65 may optionally be provided in the vapour reject line 64 resulting in that the reject vapour is fed into the end flash compressor 260 at an end-flash compressor suction temperature that is higher than the temperature at which the reject vapour is discharged from the end-flash separator 50 into the vapour reject line 64. Herewith the cold vested in the reject vapour in vapour reject 64 is preserved in a cold recovery stream 66, by heat exchanging against the cold recovery stream 66 prior to compressing the reject vapour to the end-flash compressor 260.

In one embodiment, the cold recovery stream 66 may comprise or consist of a side stream sourced from the hydrocarbon stream 110 in the liquefier 100. The resulting cooled side stream may for instance be combined with the cryogenic hydrocarbon composition in the

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cryogenic feed line 8. Thus, the cold recovery heat exchanging in the cold recovery heat exchanger 65 supplements the production rate of the cryogenic hydrocarbon composition.

5 In another embodiment, the cold recovery stream 66 may comprise or consist of a refrigerant stream being cycled in the liquefier 100 whereby the refrigerant stream (or a slipstream thereof) is condensed or sub-cooled. For instance, a slip stream of the compressed
10 refrigerant can be drawn from the compressed refrigerant line 120 (as shown in Fig. 3, which is described in more detail herein below) and be refrigerated by vapour reject line 64.

 In still another embodiment, the cold recovery stream
15 66 may comprise or consist of the aftercooled reject vapour in the compressed vapour stream line 70, preferably in the part of the compressed vapour stream line 70 that extends between the aftercooler 69 and the first auxiliary indirect heat exchanger 35 through which
20 the compressed vapour is passed from the end-flash compressor 260 to the first auxiliary indirect heat exchanger 35. Herewith the duty required from the first auxiliary refrigerant stream 132 in the first auxiliary indirect heat exchanger 35 would be reduced.

25 The first auxiliary refrigerant stream is supplied to the first auxiliary indirect heat exchanger 35 from an auxiliary refrigerant feed line 132 and discharged from the first auxiliary indirect heat exchanger 35 via an auxiliary refrigerant return line 138. An auxiliary
30 refrigerant control valve may be arranged in the auxiliary refrigerant feed line 132. A preferred method of operation of such auxiliary refrigerant control valve will be explained herein below. The auxiliary

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refrigerant control valve is not expressly shown in Fig. 1 but is included in Figs. 4 and 5 at reference 135. An auxiliary refrigerant pump may optionally be provided in the auxiliary refrigerant feed line 132. Such
5 auxiliary refrigerant pump is not expressly shown in Fig. 1, but it is included in Fig. 4 at reference 96.

As can be seen in Figure 1, the end flash compressor 260 and the optional fuel gas compressor 360 may share a single compressor driver 290. These compressors may be
10 embodied as two separate compressor casings on a common drive shaft, or they may actually be two compressor stages within a single casing.

The apparatus described above may be used in a method described as follows.

15 A cryogenic hydrocarbon composition 8 comprising a nitrogen- and methane-containing liquid phase is provided at an initial pressure of between 1 and 2 bar absolute, and an initial temperature. Providing of the cryogenic hydrocarbon composition 8 may comprise passing a
20 hydrocarbon stream 110 through the liquefier 100. The hydrocarbon stream 110 may be condensed and subcooled in the liquefier 100. The condensing and subcooling of the hydrocarbon stream 110 preferably involves indirectly heat exchanging the hydrocarbon stream 110 against a
25 refrigerant in the liquefier 100. The thus formed subcooled liquefied hydrocarbons stream is referred to as the raw liquefied stream. Thus the raw liquefied stream is formed out of the hydrocarbon stream by condensing and subsequently subcooling the hydrocarbon stream.

30 For example, in such a liquefier 100, the hydrocarbon stream 110 comprising a hydrocarbon-containing feed vapour may be heat exchanged, for example in a cryogenic heat exchanger, against a main refrigerant stream,

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thereby liquefying the feed vapour of the feed stream to provide the raw liquefied stream within the rundown line 1. The desired cryogenic hydrocarbon composition 8 may then be obtained from the raw liquefied stream 1. The raw liquefied stream may be discharged in the rundown line 1 from the liquefier 100. The cryogenic hydrocarbon composition 8 may be obtained from the raw liquefied stream, for instance by passing the raw liquefied stream through a pressure reduction step in pressure reduction system 5. In this pressure reduction step, the pressure may be reduced from the liquefaction pressure to the initial pressure.

The cryogenic hydrocarbon composition 8 is subsequently phase separated, at a first separation pressure of between 1 and 2 bar absolute, into a vaporous reject stream 64 and a liquid stream 90. Suitably, this phase separating is performed in the end-flash separator 50. The vaporous reject stream 64 comprises a majority of, preferably all of, any flash vapour that has been generated during the pressure reduction step. The liquid stream 90 is discharged in the form of the liquefied hydrocarbon stream, which may be a liquefied natural gas stream provided that the methane content is at least 81 mol%. The liquid stream 90 is typically conveyed to the cryogenic storage tank 210.

The vaporous reject stream 64 is discharged from the end-flash separator 50, and subsequently compressed in the end-flash compressor 260 to a pressure of above 2 bar absolute, thereby obtaining a compressed vapour stream 70. The compressed vapour stream 70 is split into a first compressed vapour part stream 71 and a second compressed vapour part stream 72. The first compressed vapour part stream is discharged from the stream splitter

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75 into and conveyed to the gas/liquid separator 33 in the first branch 71, while the second compressed vapour part stream is discharged from the stream splitter 75 into and conveyed to the gas/liquid separator 33 in the second branch 72. The first compressed vapour part stream and second compressed vapour part stream both have the same composition and phase as the compressed vapour 70.

If an aftercooler 69 is provided in the compressed vapour stream line 70, the compressed vapour stream 70 is passed through the aftercooler 69 as it is being passed to the stream splitter 75. In the aftercooler 69, heat is rejected from the compressed vapour to the ambient (for instance by heat exchanging against an ambient air stream or an ambient water stream). The compressed vapour 70 is discharged from the optional aftercooler 69 at an aftercooled temperature that is close to ambient temperature, for instance 2 °C above ambient temperature. Ambient temperature is considered to be the temperature of the ambient medium (air or water) to which the heat is rejected.

The part of the compressed vapour stream 70 from which heat is passed to the first auxiliary refrigerant stream 132 is formed by the first compressed vapour part stream. However, prior to passing the heat from the first compressed vapour part stream to the first auxiliary refrigerant stream 132, the first compressed vapour part stream may optionally be indirectly heat exchanged against the vapour fraction 80 from the gas/liquid separator 33 in the cold recovery heat exchanger 85. Downstream of this heat exchanging, the vapour fraction 80 is warmer than between the gas/liquid separator 33 and the cold recovery heat exchanger 85. It

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may then be combusted in the combustion device 220 as explained hereinbefore.

5 The part of the compressed vapour stream that is indirectly heat exchanged in the second auxiliary indirect heat exchanger 285 against the condensed fraction 40 is formed by the second compressed vapour part stream. This way, the partially condensed intermediate stream that is fed into the gas/liquid separator 33 is formed by the combination of the first and second compressed part streams. The partially condensed intermediate stream comprises a condensed fraction 40 and a vapour fraction 80.

10 The splitting of the compressed vapour is preferably performed with an adjustable split ratio. The split ratio corresponds to the quotient of mass flow rates in the second branch 71 and the compressed vapour line 70. The split ratio may be adjusted in response to a temperature signal representative of the temperature of the vapour fraction 80 from the gas/liquid separator 33 being discharged from the cold recovery heat exchanger 85 before being combusted. This temperature is preferably maintained at a pre-determined target value by adjusting the split ratio, and this way it will be possible to achieve a certain degree of cold recovery from the vapour fraction 80 regardless of variations in the flow rate of the vapour fraction 80. The flow rate of first compressed vapour part stream, which functions as the cold recovery fluid, is effectively assimilated to the available flow rate of the vapour fraction 80. To this end, a second temperature sensor 77 may be provided in the vapour fraction line 80 between the cold recovery heat exchanger 85 and the combustion device 220, which is electronically coupled to the split ratio control valve

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76 such that the valve setting of the split ratio control valve 76 is controlled using the signal representative of the temperature generated in the second temperature sensor 77. A second target temperature setting for this control loop may be set at a few degrees below, e.g. 2 °C below, the temperature of the cold recovery fluid 86 at the inlet of the cold recovery heat exchanger 85. If the temperature of the vapour fraction 80 at the outlet of the cold recovery heat exchanger 85 is still lower than the second target temperature, the split ratio may be adjusted to be increased (for instance by reducing the flow opening in the split ratio control valve 76). Additional control strategies known to the person skilled in the art may be implemented to avoid pinching of the cold recovery heat exchanger 85 when it is regulated on the outlet temperature.

Preferably, the temperature of the vapour fraction 80 at the outlet of the cold recovery heat exchanger 85 is between ambient temperature and at most 10 °C below ambient temperature, to obtain the most cold recovery out of the vapour fraction 80.

A partially condensed intermediate stream is formed from the first compressed vapour part stream 71 and the second compressed vapour part stream 72. This involves indirect heat exchanging of the first compressed vapour part stream 71 against the first auxiliary refrigerant stream 132, and indirectly heat exchanging the second compressed vapour part stream against a second auxiliary refrigerant stream, and subsequently recombining both part streams. The second auxiliary refrigerant stream is formed out of the condensed fraction 40 by passing the condensed fraction 40 through the pressure reduction valve 245. During the indirect heat exchanging, heat

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passes from the first compressed vapour part stream 71 to the first auxiliary refrigerant stream 132 and from the second compressed vapour part stream 72 to the second auxiliary refrigerant stream. Particularly the first compressed vapour part stream 71 against the first auxiliary refrigerant stream 132 results in partially condensing of the first compressed vapour part stream.

The condensed fraction 40 is then separated from the vapour fraction 80 in the gas/liquid separator 33, at a second separation pressure. Preferably, the vapour fraction and the condensed fraction co-exist in the gas/liquid separator 33, and are separated in a single thermodynamic equilibrium state between said vapour fraction and the condensed fraction residing inside the gas/liquid separator 33. This can generally be achieved if the gas/liquid separator 33 is embodied in the form of simple drum with no gas/liquid contacting internals such as trays or packing, thus essentially representing one single theoretical stage.

The vapour fraction 80 is discharged from the gas/liquid separator 33, typically as a vapour phase in its dew point. The vapour fraction 80, as it is being discharged from the gas/liquid separator 33, has a first heating value. The vapour fraction 80 is combusted in the combustion device 220.

The condensed fraction 40 is also discharged from the gas/liquid separator 33, but as liquid phase at its bubble point. The condensed fraction 40 is subsequently revaporized in second auxiliary indirect heat exchanger 285. The revaporizing comprises bringing the condensed fraction 40 in indirect heat exchanging contact with the second compressed vapour part stream 72, whereby heat is transferred from the second compressed vapour part stream

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72 to the condensed fraction 40. During revaporizing the condensed fraction 40 is transformed into a fully vaporized stream having a second heating value. After revaporizing, the condensed fraction 40 is fully in vapour phase. The fully vaporized stream resulting from the condensed fraction 40 is combusted in a gas turbine 320.

The nitrogen content of the liquid stream 90 may be kept within specification over the range of rundown temperatures anticipated during operation by the correct choice and dimensioning of the end-flash separator 50 at the design stage.

The first and second heating values define the amount of heat that can be released by combustion of a mole of the fuel gas. This can be either the so-called "high" heating value as the "low" heating value as long as the same conditions are used for comparing the two heating values. Preferably the "low" heating value is used to compare the two heating values, as this is the closest to the combustion conditions used in the invention. The heating value may be determined using ASTM D3588-98 applied regardless of the composition of the vapour fraction 80 and/or the condensed fraction 40. As a result of the separation in the cooled gas/liquid separator 33, the second heating value (belonging to the condensed fraction 40) is higher than the first heating value (belonging to the vapour fraction 80). However, as the partially condensed intermediate stream essentially consists of two components, methane and nitrogen, the first and second heating values uniquely map onto nitrogen content of the vapour fraction 80 and the condensed fraction 40, respectively.

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The vapour fraction 80 is combusted the combustion device 220 preferably at a first fuel gas pressure that is not higher than the second separation pressure. This way a compressor can be avoided as the pressure in the vapour fraction 80 does not have to be increased.

5 Preferably, the vapour fraction 80 is combusted in the combustion device at a pressure of between 2 and 15 bara, more preferably at a pressure of between 2 and 6 bara.

The condensed fraction 40 may have to be pressurized to a second fuel gas pressure that is higher than the second separation pressure. If a fuel gas compressor 360 is arranged in the condensed fraction discharge line 40 between the second auxiliary indirect heat exchanger 285 and the gas turbine 320, the fully vaporized stream may optionally be compressed in such fuel gas compressor 360 to the second fuel gas pressure before combusting the fully vaporized stream in the gas turbine 320. The second fuel gas pressure is generally higher than the second separation pressure, and preferably adapted to meet fuel gas pressure requirements imposed by the selected gas turbine 320.

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The pressure reduction valve 245 allows for flashing some of the condensed fraction 40 prior to passing the condensed fraction 40 through the second auxiliary indirect heat exchanger 285, by first passing the condensed fraction 40 through the pressure reduction valve 245 and subsequently performing the indirectly heat exchanging of the condensed fraction 40 against the second compressed vapour part stream 72. Herewith a lower temperature of second compressed vapour part stream 72 can be achieved when it is discharged from the second auxiliary indirect heat exchanger 285 and/or more of the cold vested in the condensed fraction 40 can be recovered

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into the second compressed vapour part stream. The pressure reduction valve 245 controls the discharge temperature of the vaporized stream being discharged from the second auxiliary indirect heat exchanger 285. The pressure reduction valve 245 may suitably be functionally coupled to a first temperature sensor 247, arranged in the condensed fraction discharge line 40 downstream of the second auxiliary indirect heat exchanger 285, whereby the valve setting is controlled in response to a first temperature signal generated in the first temperature sensor 247. If the optional fuel gas compressor 390 is provided, the first temperature sensor is suitably arranged in the condensed fraction discharge line 40 between the second auxiliary indirect heat exchanger 285 and the optional fuel gas compressor 390. A first target temperature setting for this control loop may be set at a few degrees below, e.g. 2 °C below, the temperature of the second compressed vapour part stream at the inlet of the second auxiliary indirect heat exchanger 285. Preferably, the temperature of the condensed fraction 40 at the outlet of the second auxiliary indirect heat exchanger is between ambient temperature and 10 °C below ambient temperature to effectively obtain the most benefit from the cold vested in the condensed fraction 40.

The second separation pressure is preferably higher than the first separation pressure. The second separation pressure may suitably be between 2 and 22 bara, preferably between 5 and 22 bara, more preferably between 5 and 15 bara. A second separation pressure in the higher end of the range of 2 to 22 bara helps the partial condensation of the compressed stream 70 and to provide clearance for a higher pressure drop in the

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optional pressure reduction valve 245 and/or to maintain a higher pressure even after the pressure reduction valve 245, which saves on fuel gas compression duty in the optional fuel gas compressor 360. The lower end of the range helps the separation efficiency in the gas/liquid separator 33 and causes less over compressing of the vapor fraction 80 which is to be combusted in the combustion device 220 at a relatively low pressure of typically less than 15 bara. The proposed range of between 5 and 15 bara for the second separation pressure strikes a proper balance between the beneficial and the adverse effects summarized earlier in this paragraph.

A typical pressure drop of between 1.0 and 4.0 bar over the optional pressure reduction valve 245 has been found adequate in typical cases.

In some embodiments, the second separation pressure is in the range of from 5 to 8 bara, which pressure most often meets the requirements of a low-pressure fuel gas stream suitable for conveying the vapour fraction 80 to the combustion device 220 without need for further compression. A higher pressure may be selected if the combustion device 220 is at a relatively large distance from the first gas/liquid phase separator and/or when the vapour fraction 80 is intended to pass through one or more cold recovery heat exchangers 85. In such circumstances an additional pressure drop may be expected in the course of conveying the off gas to the combustion device 220. In one embodiment, the second separation pressure is about 6.5 bara.

The cryogenic hydrocarbon composition 8 may be obtained from natural gas or petroleum reservoirs or coal beds. As an alternative the cryogenic hydrocarbon composition 8 may also be obtained from another source,

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including as an example a synthetic source such as a Fischer-Tropsch process. Preferably the cryogenic hydrocarbon composition 8 comprises at least 50 mol% methane, more preferably at least 80 mol% methane. A preferred initial temperature of lower than -130 °C may be achieved by passing a hydrocarbon stream 110 through a liquefaction system 100. An embodiment of a liquefaction system 100 and of passing the hydrocarbon stream 110 through the liquefaction system 100 will be described in more detail below.

In the example embodiment shown in Fig. 3, liquefier 100 comprises a refrigerant circuit 101 for cycling a refrigerant. The refrigerant circuit 101 comprises a refrigerant compressor 160 coupled to a refrigerant compressor driver 190 in a mechanical driving engagement. The refrigerant compressor 160 is arranged to compress a spent refrigerant stream 150 and to discharge the refrigerant, in a pressurized condition, into a compressed refrigerant line 120. At least one reject heat exchanger 124 is normally provided in the compressed refrigerant line 120 of the refrigerant circuit 101. The reject heat exchanger 124 is arranged to reject heat from the pressurized refrigerant stream carried in the compressed refrigerant line 120 to the ambient, either to the air or to a body of water such as a lake, a river, or the sea.

The liquefier 100 typically comprises a refrigerant refrigerator arranged to refrigerate the pressurized refrigerant from the compressed refrigerant line 120 from which heat has been rejected in the reject heat exchanger 124. Herewith a refrigerated refrigerant stream is obtained in a refrigerated refrigerant line 131.

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The liquefier 100 further comprises a cryogenic heat exchanger 180 connected to the refrigerant compressor 160 discharge outlet via the compressed refrigerant line 120. In the embodiment of Figure 3, the cryogenic heat exchanger 180 also fulfils the function of the refrigerant refrigerator discussed in the previous paragraph, but this is not a requirement of the invention. The cryogenic heat exchanger is generally arranged to establish an indirect heat exchanging contact between a hydrocarbon stream 110 and the refrigerant of the refrigerant circuit 101.

A spent refrigerant line 150 connects the cryogenic heat exchanger 180 with a main suction end of the refrigerant compressor 160. The refrigerated refrigerant line 131 is in fluid communication with the spent refrigerant line 150, via a cold side of the cryogenic heat exchanger 180. The hydrocarbon stream 110 flows through a warm side of the cryogenic heat exchanger 180. The cold side and the warm side are in heat exchanging contact with each other.

A main refrigerant return line 133 establishes fluid communication between the refrigerated refrigerant line 131 and the cold side of the cryogenic heat exchanger 180. The main refrigerant return line 133 is in fluid communication with the spent refrigerant line 150, via said cold side and in heat exchanging arrangement with the hot side. A main refrigerant control valve 134 is configured in the main refrigerant return line 133.

The cryogenic heat exchanger 180 receives the refrigerant stream in a depressurized condition from the main refrigerant return line 133 via the main refrigerant control valve 134, and discharges into the refrigerant

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compressor 160. Thus, the cryogenic heat exchanger 180 forms part of the refrigerant circuit 101.

The cryogenic heat exchanger 180 may be provided in any suitable form, including a printed circuit type, a plate fin type, optionally in a cold box configuration, or a tube-in-shell type heat exchanger such as a coil wound heat exchanger or a spool wound heat exchanger.

A specific non-limiting example of the liquefier and its refrigerant circuit based on a tube-in-shell type heat exchanger and including the refrigerant compressor and the cryogenic heat exchanger is included in Figures 4 and 5. These figures will be described in detail later below.

A refrigerant is cycled in the refrigerant circuit 101 of the liquefier 100. Cycling comprises driving the refrigerant compressor 160, and compressing the refrigerant stream in the refrigerant compressor 160. A hydrocarbon stream 110 is condensed and subcooled. The condensing and subcooling involves indirectly heat exchanging the hydrocarbon stream 110 against the refrigerant in the liquefier 100. The thus formed subcooled liquefied hydrocarbons stream is referred to as raw liquefied stream. Thus the raw liquefied stream is formed out of the hydrocarbon stream by condensing and subsequently subcooling the hydrocarbon stream.

The hydrocarbon stream 110 in any of the examples disclosed herein may be obtained from natural gas or petroleum reservoirs or coal beds. As an alternative the cryogenic hydrocarbon composition 8 may also be obtained from another source, including as an example a synthetic source such as a Fischer-Tropsch process. Preferably the cryogenic hydrocarbon stream 110 comprises at least 50 mol% methane, more preferably at least 80 mol%

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methane. The resulting liquid hydrocarbon product conveyed in the liquid hydrocarbon product line 90 and/or stored in the cryogenic storage tank 210 is preferably liquefied natural gas (LNG).

5 Depending on the source, the hydrocarbon stream 110 may contain varying amounts of components other than methane and nitrogen, including one or more non-hydrocarbon components other than water, such as CO₂, Hg, H₂S and other sulphur compounds; and one or more
10 hydrocarbons heavier than methane such as in particular ethane, propane and butanes, and, possibly lesser amounts of pentanes and aromatic hydrocarbons. Hydrocarbons with a molecular mass of at least that of propane may herein be referred to as C₃+ hydrocarbons, and hydrocarbons with
15 a molecular mass of at least that of ethane may herein be referred to as C₂+ hydrocarbons.

 If desired, the hydrocarbon stream 110 may have been pre-treated to reduce and/or remove one or more of undesired components such as CO₂ and H₂S, or have
20 undergone other steps such as pre-pressurizing or the like. Such steps are well known to the person skilled in the art, and their mechanisms are not further discussed here. The composition of the hydrocarbon stream 110 thus varies depending upon the type and location of the gas
25 and the applied pre-treatment(s).

 The raw liquefied stream is discharged in the rundown line 1 from the liquefier 100. The raw liquefied stream may comprise in the range of from 1 mol% to 7 mol% nitrogen and more than 81 mol% of methane. The
30 temperature of the raw liquefied stream in the rundown line 1 may be anywhere between -165 °C and -120 °C. A cryogenic hydrocarbon composition 8 is obtained from the raw liquefied stream by passing the raw liquefied stream

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through a pressure reduction step in pressure reduction system 5, whereby reducing the pressure from the liquefaction pressure to an initial pressure of between 1 and 2 bar absolute. Flash vapour is usually generated during such pressure reduction step.

The cryogenic hydrocarbon composition 8 comprises a nitrogen- and methane-containing liquid phase, and is usually at a temperature lower than -130 °C.

In many cases, the temperature of the raw liquefied stream in the rundown line 1 may be in the range of from -160 °C to -145 °C. Within this more narrow range the cooling duty needed in the liquefaction system 100 is lower than when lower temperatures are desired, while the amount of sub-cooling at the pressure of above 15 bara is sufficiently high to avoid excessive production of flash vapours upon reducing the pressure to the initial pressure of between 1 and 2 bara.

The liquefaction system 100 in the present specification, which has so far been depicted very schematically, can represent any suitable hydrocarbon liquefaction system and/or process, in particular any natural gas liquefaction process producing liquefied natural gas, and the invention is not limited by the specific choice of liquefaction system. Examples of suitable liquefaction systems employ single refrigerant cycle processes (usually single mixed refrigerant - SMR - processes, such as PRICO described in the paper "LNG Production on floating platforms" by K R Johnsen and P Christiansen, presented at Gastech 1998 (Dubai), but also possible is a single component refrigerant such as for instance the BHP-cLNG process also described in the afore-mentioned paper by Johnsen and Christiansen); double refrigerant cycle processes (for instance the much

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applied Propane-Mixed-Refrigerant process, often abbreviated C3MR, such as described in for instance US Patent 4,404,008, or for instance double mixed refrigerant - DMR - processes of which an example is described in US Patent 6,658,891, or for instance two-cycle processes wherein each refrigerant cycle contains a single component refrigerant); and processes based on three or more compressor trains for three or more refrigeration cycles of which an example is described in US Patent 7,114,351.

Other examples of suitable liquefaction systems are described in: US Patent 5,832,745 (Shell SMR); US Patent 6,295,833; US Patent 5,657,643 (both are variants of Black and Veatch SMR); US Pat. 6,370,910 (Shell DMR). Another suitable example of DMR is the so-called Axens LIQUEFIN process, such as described in for instance the paper entitled "LIQUEFIN: AN INNOVATIVE PROCESS TO REDUCE LNG COSTS" by P-Y Martin *et al*, presented at the 22nd World Gas Conference in Tokyo, Japan (2003). Other suitable three-cycle processes include for example US Pat. 6,962,060; WO 2008/020044; US Pat. 7,127,914; DE3521060A1; US Pat. 5,669,234 (commercially known as optimized cascade process); US Pat. 6,253,574 (commercially known as mixed fluid cascade process); US Pat. 6,308,531; US application publication 2008/0141711; Mark J. Roberts *et al* "Large capacity single train AP-X(TM) Hybrid LNG Process", Gastech 2002, Doha, Qatar (13-16 October 2002). These suggestions are provided to demonstrate wide applicability of the invention, and are not intended to be an exclusive and/or exhaustive list of possibilities. Not all examples listed above employ (aeroderivative) gas turbines as primary refrigerant compressor drivers. It will be clear that any drivers

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other than gas turbines can be replaced for a gas turbine to enjoy the certain preferred benefits of the present invention.

5 Examples wherein in the liquefaction system 100 is based on, for instance C3MR or Shell DMR, are briefly illustrated in Figures 4 and 5. In both cases the cryogenic heat exchanger 180 in the liquefaction system 100 is selected to be a coil wound heat exchanger, comprising a warm side comprising all the tubes,
10 including lower and upper hydrocarbon product tube bundles (181 and 182, respectively), lower and upper LMR tube bundles (183 and 184, respectively) and an HMR tube bundle 185. The cold side is formed by the shell side of the cryogenic heat exchanger 180.

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

The refrigerant provided in the refrigerant circuit 101 will be referred to as "main refrigerant" to distinguish it from other refrigerants that may used in the liquefaction system 100 such as a pre-cooling
25 refrigerant 127 which may provide cooling duty to the refrigerated hydrocarbon pre-cooling heat exchanger 115. The main refrigerant in the present embodiment is a mixed refrigerant.

The refrigerant circuit 101 comprises a spent
30 refrigerant line 150, connecting the cryogenic heat exchanger 180 (in this case a shell side 186 of the cryogenic heat exchanger 180) with a main suction end of the refrigerant compressor 160, and a compressed

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refrigerant line 120 connecting the refrigerant compressor 160 discharge outlet with an MR separator 128. One or more heat exchangers are provided in the compressed refrigerant line 120, including in the present example at least one reject heat exchanger 124. The MR separator 128 is in fluid connection with the lower LMR tube bundle 183 via a light refrigerant fraction line 121, and with the HMR tube bundle via a heavy refrigerant fraction line 122.

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

At a transition point between the upper (182, 184) and lower (181, 183) tube bundles, the HMR tube bundle 185 is in fluid connection with an HMR line 141. The HMR line 141 is in fluid communication with the shell side 186 of the cryogenic heat exchanger 180 via a first HMR return line 143, in which an HMR control valve 144 is configured. Via the said shell side 186, and in heat exchanging arrangement with each of one of the lower hydrocarbon product tube bundle 181 and the lower LMR tube bundle 183 and the HMR tube bundle 185, first HRM return line 143 is fluidly connected to the spent refrigerant line 150.

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

The refrigerant in the liquefier 100 is cycled in the refrigerant circuit 101, whereby spent refrigerant 150 is compressed in the refrigerant compressor 160 to form a compressed refrigerant 120 out of the spent refrigerant 150. Heat is removed from the compressed refrigerant discharged from the refrigerant compressor 160, via the one or more heat exchangers that are provided in the compressed refrigerant line 120 including the least one reject heat exchanger 124. This results in a partially condensed compressed refrigerant, which is phase separated in the MR separator 128 into a light refrigerant fraction 121 consisting of the vaporous constituents of the partially condensed compressed refrigerant, and a heavy refrigerant fraction 122 consisting of the liquid constituents of the partially condensed compressed refrigerant.

The light refrigerant fraction 121 is passed via successively the lower LMR bundle 183 and the upper LMR

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

Irrespective of the type of liquefier or source of the cryogenic hydrocarbon composition 8, the first auxiliary refrigerant stream 132 may suitably be formed of a slip stream of the liquefied hydrocarbon stream 90.
20 This is illustrated in Figure 4, where it can be seen that the auxiliary refrigerant feed line 132 extends between the liquid hydrocarbon product line 90 and the first auxiliary indirect heat exchanger 35. It is contemplated that only about 0.2 % of the liquefied
25 hydrocarbon stream 90 is needed as the first auxiliary refrigerant stream 132. Generally, between 0.05 and 0.40 % of the liquefied hydrocarbon stream 90 may be needed as the first auxiliary refrigerant stream 132.

In the example as shown in Figure 4, the liquefied
30 hydrocarbon product line 90 is split into the auxiliary refrigerant feed line 132 and a main product line 91. The auxiliary refrigerant return line 138 suitably extends between the first auxiliary indirect heat

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exchanger 35 and the end-flash separator 50, and is arranged to return the first auxiliary refrigerant containing heat from the first compressed vapour part stream back to the end-flash separator 50. Herewith, a
5 half-open refrigeration cycle is formed.

An advantage of employing a slip stream of the liquid stream from the liquefied hydrocarbon product line 90 for this purpose is that it can relatively easily be implemented on an already existing plant without the need
10 to interrupt or modify any part relating to the source of the cryogenic hydrocarbon composition. The amount of additional equipment to be installed is minimal. Moreover, it is the coldest stream readily available in the plant, without the need for providing a dedicated
15 refrigeration cycle, and there is generally plenty of it.

Optionally, auxiliary refrigerant pump 96 is configured in the first auxiliary refrigerant line 132, wherein the slip stream of the liquid stream 90 can be pumped to the first auxiliary indirect heat exchanger 35.

20 In another group of embodiments, and irrespective of the type of liquefier or source of the cryogenic hydrocarbon composition 8, the first auxiliary refrigerant stream 132 may suitably be formed by a slip stream of a cycled refrigerant stream from the liquefier
25 against which the hydrocarbon stream 110 has been condensed and subcooled. In such embodiments, the auxiliary refrigerant feed line 132 extends between the refrigerant circuit 101 of the liquefier 100 and the first auxiliary indirect heat exchanger 35. The
30 auxiliary refrigerant return line 138 extends between the first auxiliary indirect heat exchanger 35 and the refrigerant circuit 101 of the liquefier 100, and is arranged to return the auxiliary refrigerant containing

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heat from the compressed vapour stream back to the liquefier 100.

There are various ways to accomplish this. In preferred embodiments, the auxiliary refrigerant stream is formed by a slip stream of the main refrigerant stream, more specifically by a slip stream of the light refrigerant fraction. This latter case is illustrated in Figure 5. The refrigerated refrigerant line 131 could be split into the auxiliary refrigerant feed line 132 and the main refrigerant return line 133. The auxiliary refrigerant return line 138, on an upstream end thereof, could fluidly connect with the auxiliary refrigerant feed line 132 via the first auxiliary indirect heat exchanger 35. On a downstream end thereof, connects with the spent refrigerant line 150 via the first HMR return line 143. This way the slip stream is conveniently passed back into the main refrigerant circuit via the shell side 186 of the cryogenic heat exchanger 180, where it may still assist in withdrawing heat from the stream in the upper and/or lower tube bundles. Ultimately, the auxiliary refrigerant return line 138 thus connects with the spent refrigerant line 150. Alternatively, the auxiliary refrigerant return line 138 could directly connect with the spent refrigerant line 150.

A contemplated composition of the auxiliary refrigerant in this group of embodiments contains between 25 mol% and 40 mol% of nitrogen; between 30 mol% and 60 mol% of methane and up to 30 mol% of C₂ (ethane and/or ethylene), whereby the auxiliary refrigerant contains at least 95% of these constituents and/or the total of nitrogen and methane is at least 65 mol%. A composition within these ranges is may be readily available from the main refrigerant circuit if a mixed refrigerant is

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employed for sub-cooling of the liquefied hydrocarbon stream.

Employing a slip stream from the main refrigerant stream has as advantage that the amount of additional equipment to be installed is minimal. For instance, no additional auxiliary refrigerant compressor and auxiliary refrigerant condenser would be needed, which would be the case if a separate independent auxiliary refrigerant cycle would be proposed.

There may be other variants for supplying the first auxiliary refrigerant stream. However, in any case, the first auxiliary refrigerant stream does not contain any of the condensed fraction.

Furthermore, the auxiliary cooling duty transferred by the first auxiliary refrigerant stream in the first auxiliary indirect heat exchanger 35 can be altered by manipulating the auxiliary refrigerant control valve 135, which as has been illustrated in Figs. 4 and 5 may be configured in the auxiliary refrigerant feed line 132. Various control strategies are possible. For example, the auxiliary refrigerant control valve 135 is functionally coupled to an optional level controller 37 arranged in the gas/liquid separator 33 (illustrated in e.g. Fig. 1) to establish a constant liquid level in gas/liquid separator 33 by regulating the amount of partial condensation of the compressed vapour 70 that occurs in the first auxiliary indirect heat exchanger 35. Another example involves the auxiliary refrigerant control valve 135 is functionally coupled to an optional temperature sensor (not shown) arranged between the first auxiliary indirect heat exchanger 35 and the gas/liquid separator 33 to establish a constant temperature of the partially condensed intermediate stream.

A suitable set point for the temperature sensor can be derived from a desired nitrogen content of the condensed fraction 40 that is consisted with the fuel gas composition specification of the gas turbine 320. The remaining
5 nitrogen stays in the vapour fraction. The rundown temperature of raw liquefied stream in the rundown line 1 can be regulated such as to ensure that the total available heating power in the reject vapour 64 and/or the partially condensed intermediate stream meets the combined fuel gas
10 requirement of the combustion device(s) 220 and the gas turbine(s) 320. For instance, if there is too much heating power in the reject vapour 64, the rundown temperature can be lowered to reduce the amount of methane that is flashed in the pressure reduction step in pressure reduction system
15 5. The partitioning of the nitrogen over the vapour fraction 80 and the condensed fraction 40 is regulated by the auxiliary cooling duty.

Figure 6 illustrates an extended end-flash separator system as previously been described in US Pat. 6,014,869.
20 The end-flash separator 50 in this case comprises a gas/liquid contacting device (for instance in the form of packing or a collection of contacting trays), a lower inlet device 52 connected to a reboiler 55 and an upper inlet device 53. The cold recovery stream 66 consists of a side
25 stream of natural gas with the same composition as the raw liquefied stream 1. The cryogenic hydrocarbon composition 8 is assumed to consist of the cold recovery stream 66 and the raw liquefied stream 1 coming from the pressure reduction system 5. The remainder of Figure 6 corresponds
30 to Figure 1.

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Material and heat balance calculations have been performed using Pro2 simulation software, to demonstrate the feasibility of the proposed methods and apparatuses. The calculations are made for embodiments reading on
5 Figure 6. For the calculations it is assumed that the reject vapour stream 64 between the cold recovery heat exchanger 65 and the end flash compressor 260 contains the vapour from the end-flash separator 50 together with a boil-off gas stream from the cryogenic storage tank
10 210. It is further assumed that vapour bypass control valve 77, vapour recycle control valve 88, recycle valve 14, and external stripping vapour flow control valve 73 are closed and in no-flow condition.

Tables 1 to 4 show results for embodiments based on
15 Figure 6 whereby the first auxiliary refrigerant stream 132 is provided by a slip stream of the liquid stream in the liquefied hydrocarbon product stream line 90.

Tables 1 and 2 correspond to one calculation wherein the second separation pressure falls in the range of from
20 4 to 8 bara. This is referred to as the low pressure case. Tables 3 and 4 correspond to another calculation, which is referred to as the high pressure case. In the other calculation the second separation pressure falls in the range of from 10 to 20 bara. This affects the
25 pressure drop that is available over the pressure reduction valve 245, which in turn affects the cooling duty that is available in second auxiliary indirect heat exchanger 285. This, of course, at the cost of extra compression power. It can be seen that the temperature
30 under which the phase separation in the gas/liquid separator 33 is performed can be higher in this pressure range. Notwithstanding, a larger amount of the liquid

Table 1 (low pressure case)

Stream Nr.	1	1a	1b	8	60	66	90	138
Pressure (bara)	74.8	74.2	9.88	1.05	1.05	9.88	1.12	1.50
Temperature (°C)	-155	-163	-164	-167	-167	-157	-163	-134
Flow rate (kg/s)	211	211	211	218	19.4	6.65	198	0.30
Nitrogen (mol.%)	3.93	3.93	3.93	3.93	41.4	3.93	1.09	1.09
Methane (mol.%)	95.7	95.7	95.7	95.7	58.6	95.7	98.5	98.5
C ₂ ⁺ (mol.%)	0.39	0.39	0.39	0.39	0.00	0.39	0.42	0.42

Table 2 (low pressure case, continued)

Stream Nr.	8	40	64	70	71	71a	71b	72	80	90	132	138	230	240
Pressure (bara)	1.05	6.50	0.85	7.50	7.50	7.00	6.50	7.00	6.50	1.12	2.00	1.50	1.00	3.00
Temperature (°C)	-167	-162	-27	+31	+31	-131	-142	-169	-162	-163	-163	-134	-159	-172
Flow rate (kg/s)	218	19.6	23.7	23.7	3.48	3.48	3.48	20.3	4.12	198	0.30	0.30	3.20	19.6
Nitrogen (mol.%)	3.93	29.0	36.8	36.8	36.8	36.8	36.8	36.8	86.4	1.09	1.09	1.09	17.3	29.0
Methane (mol.%)	95.7	71.0	63.2	63.2	63.2	63.2	63.2	63.2	13.6	98.5	98.5	98.5	82.7	71.0
C ₂ ⁺ (mol.%)	0.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.42	0.42	0.42	0.00	0.00

Table 3 (high pressure case)

Stream Nr.	1	1a	1b	8	60	66	90	138
Pressure (bara)	74.8	74.2	9.88	1.05	1.05	9.73	1.12	1.50
Temperature (°C)	-155	-163	-164	-167	-167	-157	-163	-128
Flow rate (kg/s)	210	210	210	217	19.4	6.58	198	0.49
Nitrogen (mol.%)	3.93	3.93	3.93	3.93	41.6	3.93	1.11	1.11
Methane (mol.%)	95.7	95.7	95.7	95.7	58.4	95.7	98.5	98.5
C ₂ ⁺ (mol.%)	0.39	0.39	0.39	0.39	0.00	0.39	0.42	0.42

Table 4 (high pressure case, continued)

Stream Nr.	8	40	64	70	71	71a	71b	72	80	90	132	138	230	240
Pressure (bara)	1.05	16.5	0.85	17.5	17.5	17.0	16.5	17.0	16.5	1.12	2.00	1.50	1.00	9.50
Temperature (°C)	-167	-135	-27	+31	+31	-125	-127	-140	-135	-163	-163	-128	-160	-144
Flow rate (kg/s)	217	12.5	23.5	23.5	8.18	8.18	8.18	15.3	10.9	198	0.49	0.49	4.32	12.5
Nitrogen (mol.%)	3.93	19.3	36.9	36.9	36.9	36.9	36.9	36.9	62.9	1.09	1.11	1.11	18.9	19.3
Methane (mol.%)	95.7	80.7	63.1	63.1	63.1	63.1	63.1	63.1	37.1	98.5	98.5	98.5	81.1	80.7
C ₂ ⁺ (mol.%)	0.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.42	0.42	0.42	0.00	0.00

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hydrocarbon stream has to be used as the first auxiliary refrigerant stream.

5 The low pressure case as calculated in the present example yields a low quality fuel gas that is discharged from the cold recovery heat exchanger 85 at a pressure of 5.00 bara and a temperature of 22 °C; and a revaporized condensed fraction that is discharged from the second auxiliary indirect heat exchanger 285 at a pressure of 3.00 bara and a temperature of 25 °C. The latter may be
10 utilized as high quality fuel gas.

 The high pressure case as calculated in the present example yields a low quality fuel gas that is discharged from the cold recovery heat exchanger 85 at a pressure of 5.00 bara and a temperature of 28 °C; and a revaporized
15 condensed fraction that is discharged from the second auxiliary indirect heat exchanger 285 at a pressure of 9.00 bara and a temperature of 19 °C. The latter may be utilized as high quality fuel gas.

 In both the low pressure case and the high pressure
20 case, the ultimate composition of the liquefied hydrocarbon inventory as stored in the cryogenic storage tank 210 is 0.83 mol.% nitrogen; 98.74 mol.% methane and 0.43 mol.% C₂+, whereby C₂+ indicates all hydrocarbons having a mass corresponding to that of ethane, and
25 upward. The liquefied hydrocarbon stream being passed through the main product line 91 to the cryogenic storage tank 210 has slightly more nitrogen than the liquefied hydrocarbon inventory as stored in the cryogenic storage tank 210.

30 Tables 5 and 6 show results for embodiments based on Figure 6 whereby the first auxiliary refrigerant stream 132 is provided by a slip stream from the refrigerated refrigerant line 131. In this case, the molecular weight

Table 5 (low pressure case)

Stream Nr.	1	1a	1b	8	60	66	90
Pressure (bara)	74.8	74.2	9.90	1.05	1.05	9.90	1.12
Temperature (°C)	-155	-162	-163	-167	-167	-156	-163
Flow rate (kg/s)	211	211	211	218	19.4	6.70	198
Nitrogen (mol.%)	3.93	3.93	3.93	3.93	41.3	3.93	1.09
Methane (mol.%)	95.7	95.7	95.7	95.7	58.7	95.7	98.5
C ₂ ⁺ (mol.%)	0.39	0.39	0.39	0.39	0.00	0.39	0.42

Table 6 (low pressure case, continued)

Stream Nr.	8	40	64	70	71	71a	71b	72	80	90	132	138	230	240
Pressure (bara)	1.05	6.50	0.85	7.50	7.50	7.00	6.50	7.00	6.50	1.12	6.95	6.45	1.00	3.00
Temperature (°C)	-167	-162	-26	+31	+31	-130	-142	-169	-162	-163	-157	-142	-160	-172
Flow rate (kg/s)	218	19.7	23.7	23.7	3.47	3.47	3.47	20.3	4.09	198	1.73	1.73	4.32	19.7
Nitrogen (mol.%)	3.93	29.0	36.7	36.7	36.7	36.7	36.7	36.7	86.4	1.09	21.6	21.6	18.6	29.0
Methane (mol.%)	95.7	71.0	63.3	63.3	63.3	63.3	63.3	63.3	13.6	98.5	58.6	58.6	81.4	71.0
C ₂ ⁺ (mol.%)	0.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.42	19.8	19.8	0.00	0.00

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of the auxiliary refrigerant 132, which contains 21.6 mol% of nitrogen, 58.6 mol% of methane, and 19.8 mol% of C₂+ components (mostly ethane) is MW = 21.59. C₂+ indicates all hydrocarbons having a mass corresponding to that of ethane, and upward. In the case of the LMR refrigerant C₂+ consists mostly of ethane. Tables 5 and 6 correspond to one calculation, wherein the second separation pressure falls in the range of from 4 to 8 bara.

As calculated in the present example a low quality fuel gas is discharged from the cold recovery heat exchanger 85 at a pressure of 5.00 bara and a temperature of 28 °C; and a revaporized condensed fraction that is discharged from the revaporizer 285 at a pressure of 3.00 bara and a temperature of 25 °C. The latter may be utilized as high quality fuel gas.

The ultimate composition of the liquefied hydrocarbon inventory as stored in the cryogenic storage tank 210 is 0.82 mol% nitrogen; 98.75 mol% methane and 0.43 mol% C₂+. The liquefied hydrocarbon stream being passed through the main product line 91 to the cryogenic storage tank 210 has slightly more nitrogen than the liquefied hydrocarbon inventory as stored in the cryogenic storage tank 210.

In any of the examples above, a preferred range of liquefaction pressure, at which raw liquefied stream is discharged in the rundown line 1 from the liquefier 100, is from 15 bara to 120 bara, more preferably from 15 bara to 90 bara or from 45 bara to 120 bara. The most preferably range for the liquefaction pressure is from 45 bara to 90 bara. In case that the raw liquefied stream consists for at least 80 mol% of methane and nitrogen, a preferred temperature range for the raw liquefied stream in the rundown line 1 may be from -165 °C to -120 °C.

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In any of the examples above, the vapour fraction 80 is envisaged to contain in the range of from 30 mol% to 90 mol% of nitrogen, preferably in the range of from 30 mol% to 80 mol% of nitrogen or in the range of from 45 mol% to 90 mol% of nitrogen, preferably in the range of from 45 mol% to 80 mol% of nitrogen, most preferably from 50 mol% to 80 mol% of nitrogen. To achieve a content of nitrogen of between 50 mol% and 80 mol%, such as about 60 mol%, sufficient methane must be recondensed from the compressed vapour stream 70. This may for instance be done using a pressure of the compressed vapour stream 70 of between 4 and 8 bara, and achieving a temperature of the partially condensed intermediate stream of in the range of from -150 °C to -135 °C. The temperature range may have higher end points if the pressure is higher than 8 bara.

Furthermore, the condensed fraction 40 generally contains up to 30 mol% of nitrogen, and not less than 5 mol%, preferably not less than 10 mol%. Striving for lower values would cost more auxiliary cooling duty whereas that is not needed for typical gas turbines and particularly not for aero derivative gas turbines.

Compressors forming part of the hydrocarbon liquefaction process in the liquefaction system 100, particularly any refrigerant compressor including refrigerant compressor 160, may be driven by any type of suitable compressor driver 190, including any selected from the group consisting of gas turbine; steam turbine; and electric motor; and inter combinations thereof. This generally applies also to refrigerant compressor driver 190.

The gas turbine may be selected from the group of so-called industrial gas turbines, or the group of so-called

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aeroderivative gas turbines. The group of aeroderivative gas turbines includes: Rolls Royce Trent 60, RB211, or 6761, and General Electric LMS100TM, LM6000, LM5000 and LM2500, and variants of any of these (e.g. LM2500+).

5 Suitably, the gas turbine 320 in which the condensed fraction 40 is ultimately combusted is the refrigerant compressor driver 190 that is in driving engagement with the refrigerant compressor 160. The gas turbine 320 may drive the refrigerant compressor 160.

10 Typically, the second fuel gas pressure is selected in a range between 15 and 75 bara, more preferably in a range of between 45 and 75 bara. The usual prescribed fuel gas pressure for most conventional types of industrial gas turbines is between around 15 and around
15 25 bara, on average. However, the latest generation of industrial gas turbine requires relatively high pressure fuel gas, such as in the range of from 35 to 45 bara. The range of between 45 and 75 bara is recommended to meet fuel gas pressure requirements of typical
20 aeroderivative gas turbines.

 The nitrogen content of the liquid stream 90 typically does not exceed a desired maximum of about 1.1 mol%. In some embodiments, the amount of nitrogen in the liquid hydrocarbon stream 90 is between 0.5 and
25 1 mol%, preferably as close to 1.0 mol% as possible yet not exceeding said maximum of about 1.1 mol%.

 It is a known phenomenon that boil-off gas results from thermal evaporation caused by heat added to the liquefied product, for instance in the form of heat
30 leakage into storage tanks, LNG piping, and heat input from plant LNG pumps. In any of the examples and embodiments illustrated herein, boil-off gas may optionally be injected into the vapour reject line 64,

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either upstream or downstream of the end-flash compressor 260 to be subject to the phase separation in the gas/liquid separator 33. This may suitably comprise collecting boil-off gas from the cryogenic storage tank 210, possibly via a boil-off gas supply line 230 as is illustrated for example in Figure 6. Boil-off gas results from adding heat to at least part of the liquefied hydrocarbons, whereby a part of the methane-containing liquid phase in the liquefied hydrocarbons evaporates to form said boil-off gas.

Although not a mandatory requirement of the invention, it is contemplated that the proposed method may be operated off-shore on a floating barge. Similarly the apparatus may be installed on a floatable barge, for off-shore operation. The cryogenic storage tank may suitably be incorporated within the hull of the same barge.

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

C L A I M S

1. Method of producing a liquefied hydrocarbon stream, comprising:

- providing a cryogenic hydrocarbon composition comprising a nitrogen- and methane-containing liquid phase at an initial pressure of between 1 and 2 bar absolute;
- phase separating the cryogenic hydrocarbon composition, in an end flash separator at a first separation pressure of between 1 and 2 bar absolute, into a vaporous reject stream and a liquid stream;
- discharging the liquid stream from the end flash separator in the form of the liquefied hydrocarbon stream;
- compressing the vaporous reject stream in an end-flash compressor to a pressure of above 2 bar absolute, thereby obtaining a compressed vapour stream;
- splitting the compressed vapour into a first compressed vapour part stream and a second compressed vapour part stream whereby said first compressed vapour part stream and second compressed vapour part stream both have the same composition and phase as the compressed vapour;
- forming a partially condensed intermediate stream comprising a condensed fraction and a vapour fraction, comprising indirectly heat exchanging the first compressed vapour part stream against a first auxiliary refrigerant stream whereby passing heat from the first compressed vapour part stream to the first auxiliary refrigerant stream, and by indirectly heat exchanging the second compressed vapour part stream against a second auxiliary refrigerant stream whereby passing heat from the second compressed vapour part stream to

the second auxiliary refrigerant stream, and recombining both part streams;

- in a gas/liquid separator, separating the condensed fraction from the vapour fraction of the part streams after recombining, at a second separation pressure;
- discharging the vapour fraction from the gas/liquid separator, said vapour fraction having a first heating value;
- combusting the vapour fraction in a combustion device other than a gas turbine;
- discharging the condensed fraction from the gas/liquid separator;
- revaporizing the condensed fraction whereby transforming the condensed fraction into a fully vaporized stream having a second heating value that is higher than the first heating value;
- combusting the fully vaporized stream in a gas turbine;
wherein said revaporizing of the condensed fraction comprises said indirectly heat exchanging of the second compressed vapour part stream by passing the condensed fraction through a pressure reduction valve thereby forming the second auxiliary refrigerant stream and subsequently subjecting said second auxiliary refrigerant stream to said indirectly heat exchanging against the second compressed vapour part stream whereby fully vaporizing the condensed fraction and wherein the first auxiliary refrigerant stream does not contain any of the condensed fraction.

2. The method of claim 1, wherein said forming of the partially condensed intermediate stream comprises partially condensing at least the first compressed vapour part stream after said splitting and prior to said recombining.

3. The method of claim 1 or 2, wherein said forming of the partially condensed intermediate stream from the compressed vapour further comprises indirectly heat exchanging of the first compressed vapour part stream against the vapour fraction from the gas/liquid separator prior to said combusting of the vapour fraction in said combustion device.
4. The method of claim 3, wherein said splitting of the compressed vapour is performed with an adjustable split ratio, said method further comprising adjusting the split ratio in response to a temperature signal representative of the temperature of the vapour fraction from the gas/liquid separator being discharged from said indirectly heat exchanging against the first compressed vapour part stream whereby maintaining said temperature of the vapour fraction at a pre-determined target value.
5. The method of any one of claims 1 to 4, wherein after revaporizing the condensed fraction and before combusting the fully vaporized stream, the fully vaporized stream is compressed in a fuel gas compressor to a second fuel gas pressure of higher than the second separation pressure, and between 15 and 75 bara.
6. The method of any one of claims 1 to 5, wherein the second fuel gas pressure is between 45 and 75 bar.
7. The method of any one of claims 1 to 6, wherein the vapour fraction is combusted in said combustion device at a first fuel gas pressure not higher than the second separation pressure.
8. The method of any one of claims 1 to 7, wherein the vapour fraction is combusted in said combustion device at a pressure of between 2 and 15 bara

9. The method of any one of claims 1 to 8, , wherein the second separation pressure is between 2 and 22 bara.
10. The method of any one of claims 1 to 9, wherein the second separation pressure is between 5 and 22 bara.
11. The method of any one of claims 1 to 10, wherein the second separation pressure is between 5 and 15 bara.
12. The method of any one of claims 1 to 11, wherein the liquid stream and the liquefied hydrocarbon stream contain less than 1.1 mol% of nitrogen.
13. The method of any one of claims 1 to 12, wherein more than 30 mol% of the partially condensed intermediate stream consists of nitrogen, and less than 30 mol% of the condensed fraction being discharged from the gas/liquid separator consists of nitrogen.
14. The method of any one of claims 1 to 13, wherein the vapour fraction and the condensed fraction co-exist and are separated in one thermodynamic equilibrium state between said vapour fraction and the condensed fraction.
15. The method of any one of claims 1 to 14, wherein after said discharging of the liquid stream from the end flash separator in the form of the liquefied hydrocarbon stream, the liquefied hydrocarbon stream is conveyed to a cryogenic storage tank incorporated within a hull of a floatable barge.
16. An apparatus for producing a liquefied hydrocarbon stream, comprising:
 - a cryogenic feed line connected to a source of a cryogenic hydrocarbon composition comprising nitrogen and a methane-containing liquid phase;
 - an end-flash separator arranged to receive the cryogenic hydrocarbon composition and to separate the cryogenic

hydrocarbon composition into a liquid stream and vaporous reject stream;

- a liquid hydrocarbon product line fluidly connected to a bottom part of the end-flash separator to discharge said liquid stream in the form of the liquefied hydrocarbon stream from the end-flash separator;
- a vapour reject line fluidly connected to an overhead part of the end-flash separator to discharge said vaporous reject stream from the end-flash separator;
- an end-flash compressor arranged in the vapour reject line to compress the vaporous reject stream, thereby obtaining a compressed vapour stream;
- a stream splitter configured in the compressed vapour line, for dividing the compressed vapour line over a first branch and a second branch, whereby the first branch is arranged between the stream splitter and the gas/liquid separator, and whereby the second branch is arranged between the stream splitter and the gas/liquid separator;
- a first auxiliary indirect heat exchanger arranged in the first branch, arranged to receive a first compressed vapour part stream available in the first branch and to establish indirect heat exchanging contact between the first compressed vapour part stream and a first auxiliary refrigerant stream;
- a second auxiliary indirect heat exchanger arranged in the second branch, arranged to receive a second compressed vapour part stream available in the second branch and to establish indirect heat exchanging contact between the second compressed vapour part stream and a second auxiliary refrigerant stream;
- a gas/liquid separator arranged downstream of both the first auxiliary heat exchanger and the second auxiliary heat

exchanger, and arranged to receive a partially condensed intermediate stream from the first auxiliary heat exchanger and the second auxiliary heat exchanger, which partially condensed intermediate stream comprises a condensed fraction and a vapour fraction;

- a vapour fraction discharge line fluidly connected with an overhead part of the gas/liquid separator arranged to receive the vapour fraction from the gas/liquid separator;
- a combustion device other than a gas turbine fluidly connected with the gas/liquid separator by means of the vapour fraction discharge line to receive and combust the discharged vapour fraction;
- a condensed fraction discharge line fluidly connected with a bottom part of the gas/liquid separator arranged to receive the condensed fraction from the gas/liquid separator;
- a gas turbine fluidly connected with the gas/liquid separator by means of the condensed fraction discharge line to receive and combust the discharged condensed fraction;
- a revaporizer arranged in the condensed fraction discharge line between the gas/liquid separator and the gas turbine and arranged to transform the condensed fraction into a fully vaporized stream prior to combustion in the gas turbine;
- a pressure reduction valve arranged in the condensed fraction discharge line between the gas/liquid separator and the revaporizer;

wherein the second auxiliary heat exchanger is the revaporizer, wherein the condensed fraction downstream of the pressure reduction valve is the second auxiliary refrigerant stream, and wherein the first auxiliary refrigerant stream does not contain any of the condensed fraction.

17. The apparatus of claim 16, wherein the first auxiliary heat exchanger is a condenser arranged to extract heat from the first compressed vapour part stream available in the first branch thereby to at least partially condense the first compressed vapour part stream.

18. The apparatus of claim 16 or 17, wherein the gas/liquid separator consists of a drum free from internals forming a vapour/liquid contacting section.

19. The apparatus of any one of claims 16 to 18, further comprising a cold recovery heat exchanger configured in the vapour fraction discharge line upstream of the combustion device, which cold recovery heat exchanger is arranged in the first branch in addition to the first auxiliary heat exchanger.

20. The apparatus of any one of claims 16 to 19, wherein said liquid hydrocarbon product line fluidly connects the bottom part of the end-flash separator to a cryogenic storage tank incorporated within a hull of a floatable barge.

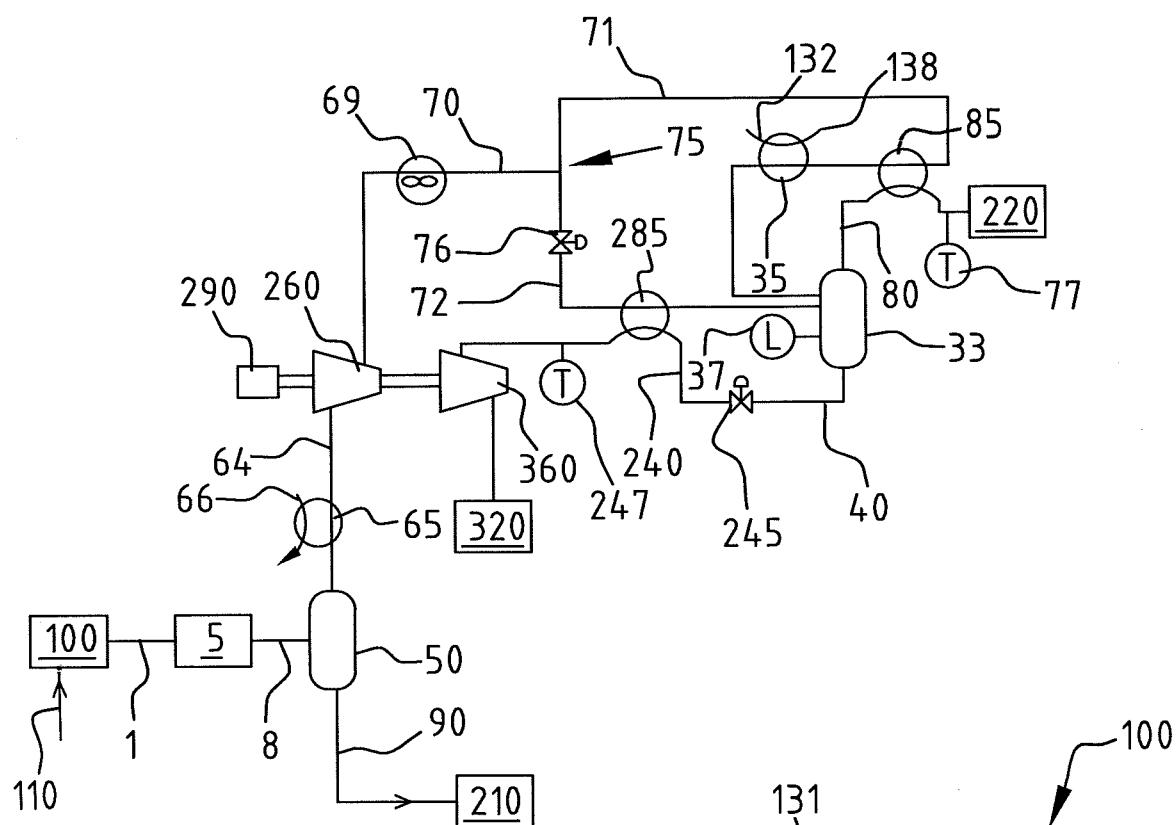
$\frac{1}{4}$ 

FIG. 1

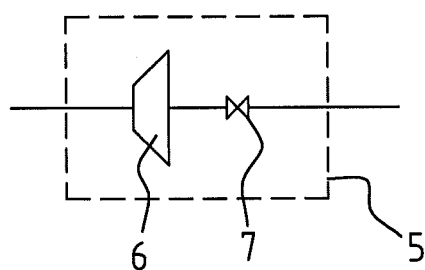


FIG. 2

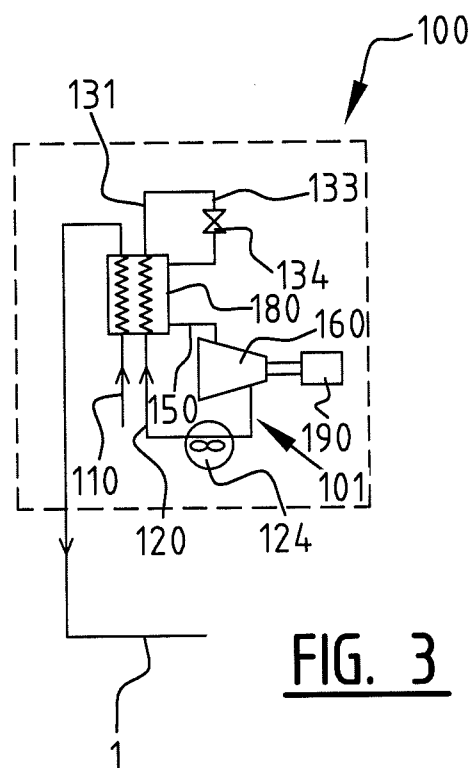


FIG. 3

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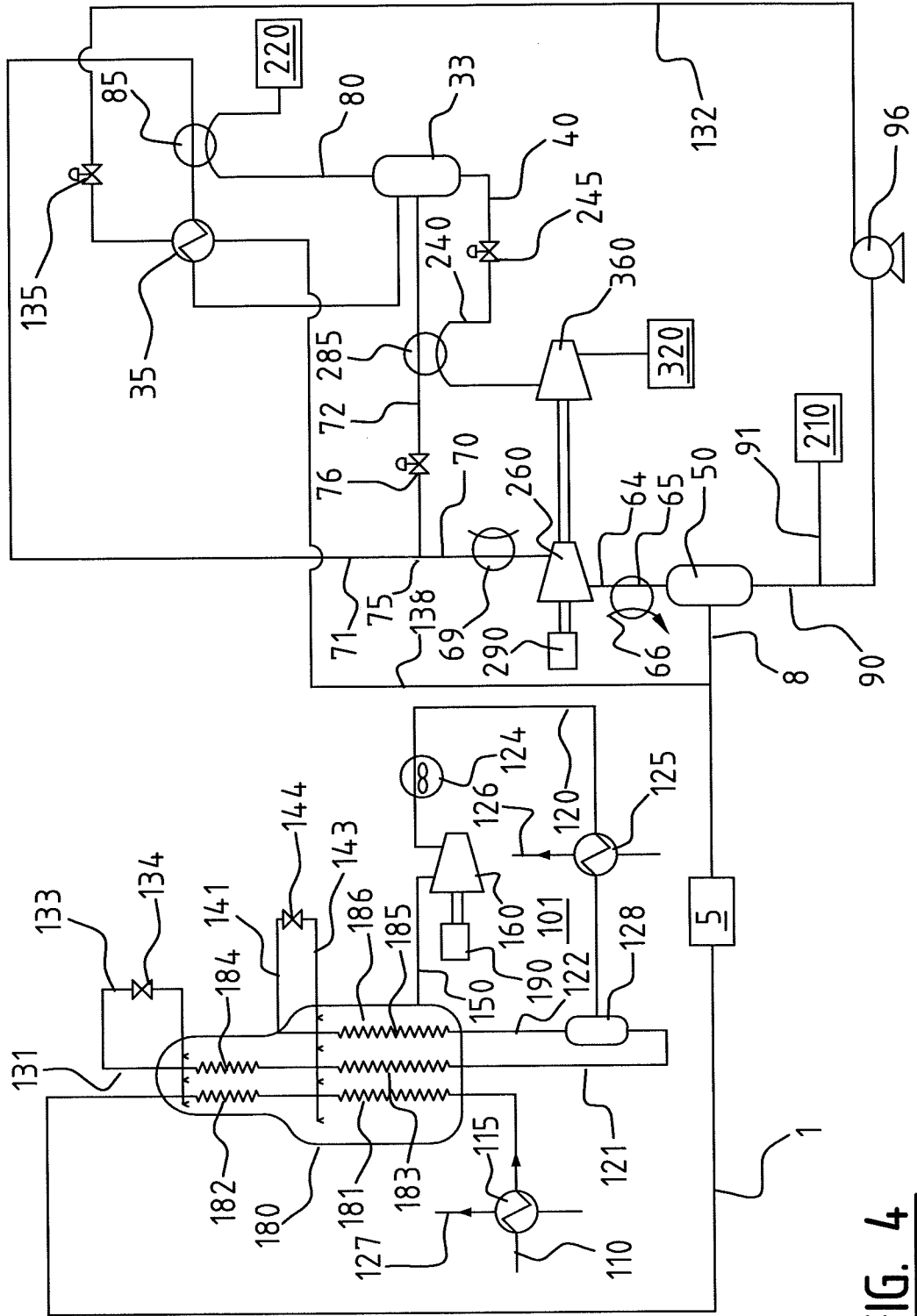


FIG. 4

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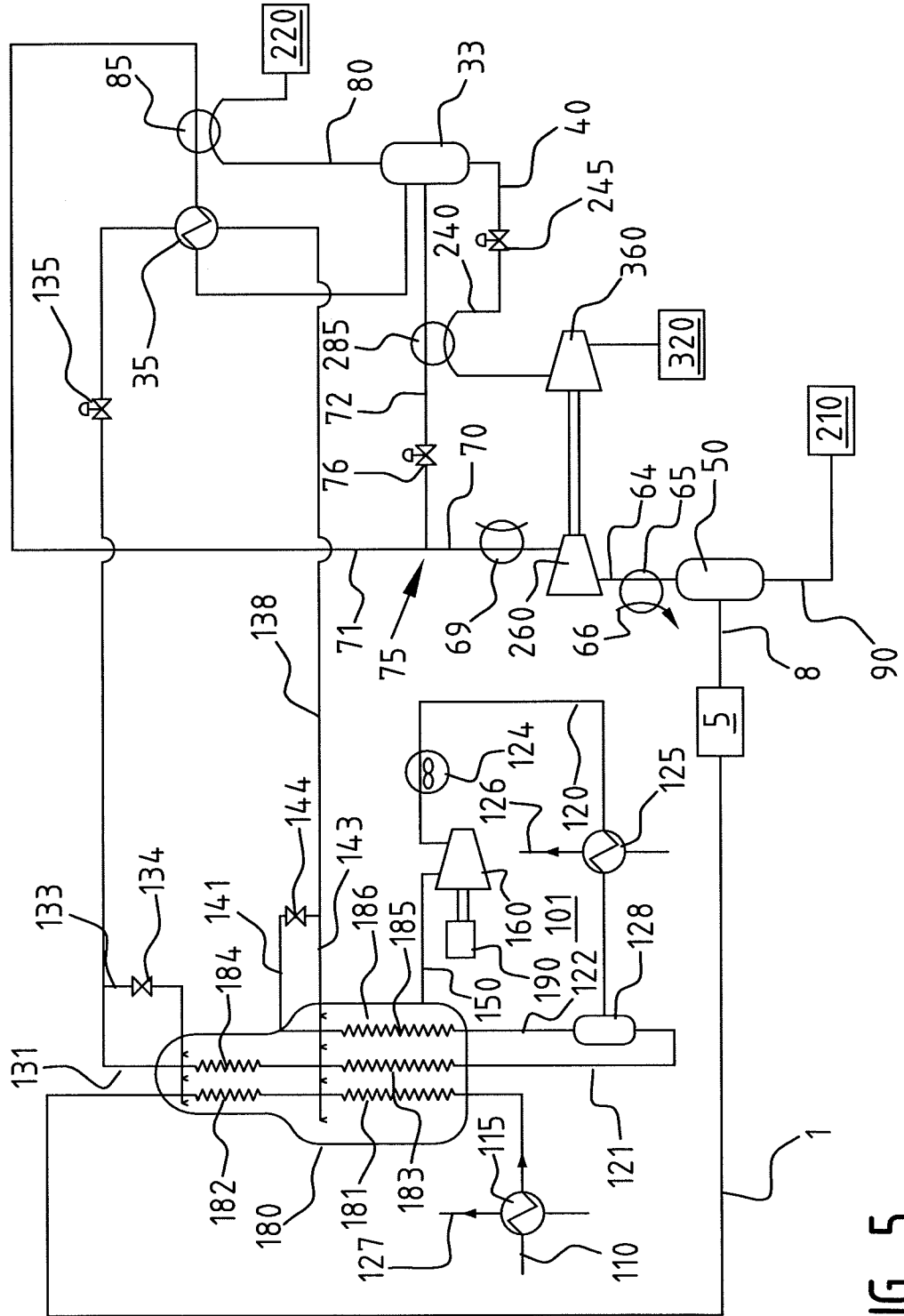


FIG. 5

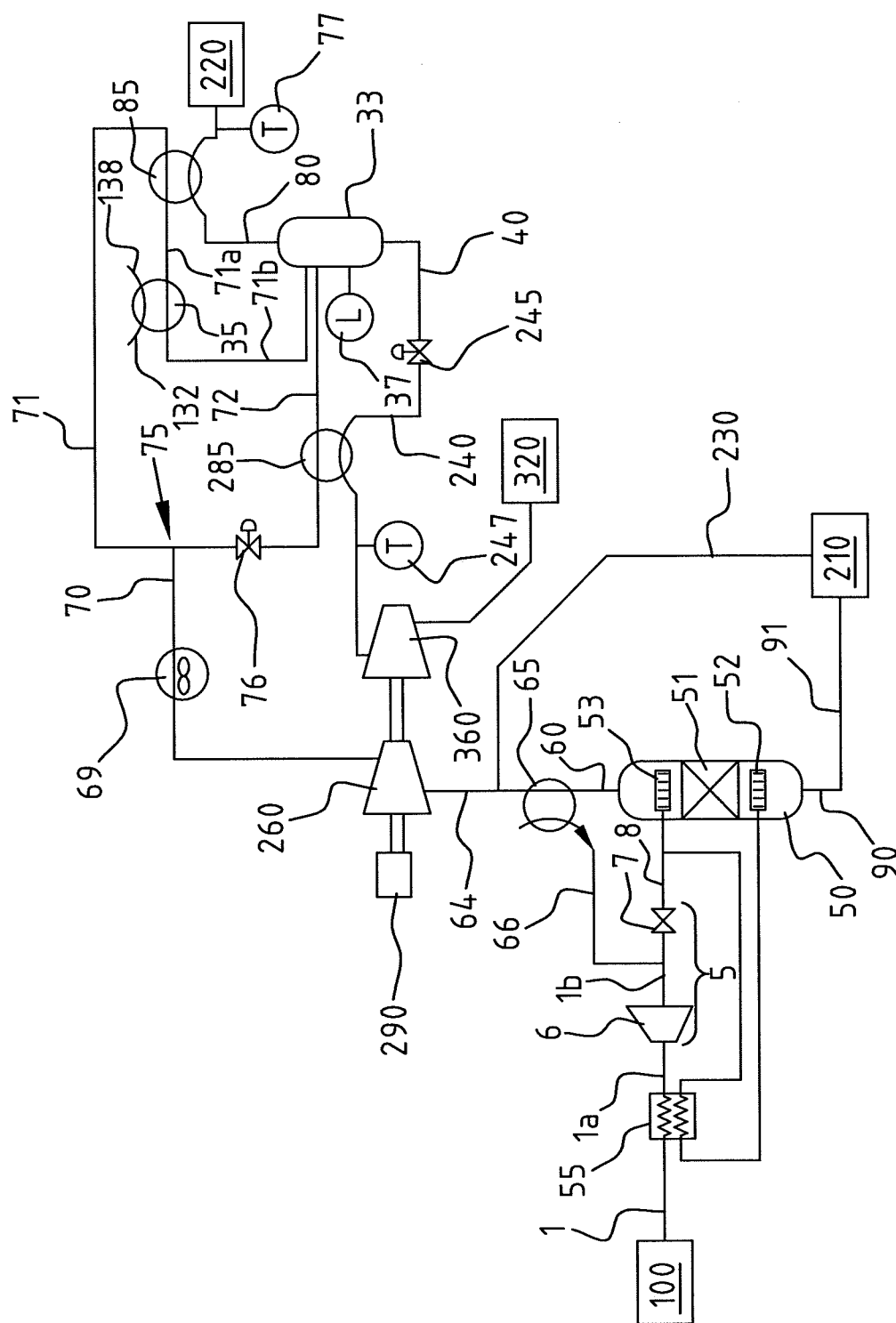


FIG. 6

