



(11)

EP 2 005 094 B1

(12)

EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention
of the grant of the patent:
30.10.2019 Bulletin 2019/44

(51) Int Cl.:
F25J 1/00 (2006.01) **F17C 13/00** (2006.01)
F25J 1/02 (2006.01)

(21) Application number: **07747584.6**

(86) International application number:
PCT/NO2007/000123

(22) Date of filing: **02.04.2007**

(87) International publication number:
WO 2007/117148 (18.10.2007 Gazette 2007/42)

(54) **METHOD AND APPARATUS FOR PRE-HEATING LNG BOIL-OFF GAS TO AMBIENT
TEMPERATURE PRIOR TO COMPRESSION IN A RELIQUEFACTION SYSTEM**

VERFAHREN UND VORRICHTUNG ZUM VORERWÄRMEN VON BOIL-OFF-FLÜSSIGERD GAS
AUF UMGEBUNGSTEMPERATUR VOR DER KOMPRIMIERUNG IN EINEM
VERFLÜSSIGUNGSSYSTEM

PROCÉDÉ ET APPAREIL PERMETTANT DE PRÉCHAUFFER UN GAZ NATUREL LIQUÉFIÉ
D'ÉVAPORATION À LA TEMPÉRATURE AMBIANTE AVANT SA COMPRESSION DANS UN
SYSTÈME DE RELIQUÉFACTION

(84) Designated Contracting States:
**AT BE BG CH CY CZ DE DK EE ES FI FR GB GR
HU IE IS IT LI LT LU LV MC MT NL PL PT RO SE
SI SK TR**

(74) Representative: **Zacco Norway AS**
Haakon VII's gate 2
PO Box 2003 Vika
0125 Oslo (NO)

(30) Priority: **07.04.2006 NO 20061580**

(56) References cited:
WO-A1-98/43029 WO-A1-03/081154
WO-A1-03/081154 WO-A1-2006/098630
GB-A- 1 471 404 US-A- 3 857 245
US-A- 5 768 912 US-A1- 2003 182 947
US-A1- 2003 182 947 US-B1- 6 192 705

(43) Date of publication of application:
24.12.2008 Bulletin 2008/52

(73) Proprietor: **Wärtsilä Gas Solutions Norway AS**
1383 Asker (NO)

(72) Inventor: **HAUKEDAL, Bjørn**
0588 Oslo (NO)

Note: Within nine months of the publication of the mention of the grant of the European patent in the European Patent Bulletin, any person may give notice to the European Patent Office of opposition to that patent, in accordance with the Implementing Regulations. Notice of opposition shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

EP 2 005 094 B1

Description

Field of the Invention

[0001] The invention relates to the field of re-liquefaction of boil-off gases from liquid natural gas (LNG). More specifically, the invention relates to a method and an apparatus for cooling an LNG boil-off gas (BOG) stream in a reliquefaction plant according to the preamble of claims 1 and 3 respectively. Such a method respectively apparatus is known from US2003/0182947 A.

Background

[0002] A new generation of LNG vessels was established in association with the introduction of LNG reliquefaction systems (LNG RS). Prior to this, basically all LNG vessels were driven by steam turbines fuelled by boil off gases (BOG) evaporating from the cargo during transportation. In periods when the total amount of BOG was insufficient to cover the entire power demand, additional LNG had to be fed to the boilers through forced vaporizers.

Brief description of the Prior Art

[0003] The new LNG RS opened the possibility to collect, cool down and reliquefy all BOG and hence preserve the total cargo volume throughout the laden and ballast voyages. Conventional slow speed diesel engines, with high efficiencies compared to the steam turbines, could then be used for propulsion.

[0004] US 2003/182947 A discloses a process for converting a boil-off stream comprising methane to a liquid having a preselected bubble point temperature. The boil-off stream is pressurized, then cooled, and then expanded to further cool and at least partially liquefy the boil-off stream. The preselected bubble point temperature of the resulting pressurized liquid is obtained by performing at least one of the following steps: before, during, or after the process of liquefying the boil-off stream, removing from the boil-off stream a predetermined amount of one or more components, such as nitrogen, having a vapor pressure greater than the vapor pressure of methane, and before, during, or after the process of liquefying the boil-off stream, adding to the boil-off stream one or more additives having a molecular weight heavier than the molecular weight of methane and having a vapor pressure less than the vapor pressure of methane.

[0005] WO 03/081154 A1 relates to a method and apparatus for production of pressurized liquefied gas. First, a gas stream is cooled and expanded to liquefy the gas stream. The liquefied gas stream is then withdrawn as pressurized gas product and a portion is recycled through the heat exchanger to provide at least a part of the cooling and is returned to the stream. Recycling the pressurized liquefied gas product helps keep the cooling and compression of the gas stream in the supercritical region of

the phase diagram. J-T valves in parallel with the expander permits running the system until the stream is in the supercritical region of its phase diagram and the hydraulic expander can operate. The process is suitable for natural gas streams containing methane to form a pressurized liquefied natural gas (PLNG) product.

[0006] Several patents have described various aspects with such reliquefaction plants, and accordingly improvements to these. The prior art (e.g. Norwegian Patent Application No 20051315 basically focuses on improvements of the nitrogen Brayton cycle and the utilization of cold nitrogen for pre-cooling. There is, however, a further need to improve the system in order to reduce the power demands.

[0007] Most of today's LNG vessels utilize low-temperature centrifugal BOG compressors to feed their boilers. Much of the reason for choosing low-temperature compression is that this will reduce the compressor size significantly compared to compression at ambient temperatures. The fan laws are applicable for centrifugal compressors, and show that a low suction temperature will ensure a higher pressure ratio per stage. The density of the gas will accordingly increase, the volume flow is reduced to a minimum, and the size and efficiency of the BOG compressors become more favourable.

[0008] Since there is no need to preserve the low temperature duty in the BOG stream - in fact the BOG is normally additionally heated before introduction to the boilers - the heat of compression is deliberately absorbed by the compressed gas without any means of heat rejection downstream the BOG compression.

[0009] The common practice of low temperature BOG compression has been further applied to new BOG compressor designs, dedicated for operation towards LNG reliquefaction systems. From an energy point-of-view this results in inefficient operation, since the cooling cycle must be sized to remove the heat of compression from BOG compressors, *in addition* to the heat of evaporation and the superheating adsorbed in the cargo containment system.

[0010] Also, other problems arise when low-temperature BOG compression is applied. Since no aftercoolers (intercoolers) are employed, recycling at low capacities depend on temperature control upstream the BOG compressor. The cooling duty necessary for this purpose can be difficult to predict since it will depend much on the BOG compressor efficiency, which in turn depends on several properties of the processed stream. Using recondensed BOG to provide this cooling, also reduces the performance of the plant, measured in terms of power per unit reliquefied BOG returned to the tanks.

Summary of the Invention

[0011] It is provided a method for cooling an LNG boil-off gas (BOG) stream in a reliquefaction plant, the BOG flowing from a reservoir, the method comprising compressing the BOG; heat exchanging the compressed

BOG against a coolant in a cold box; flowing substantially re-liquefied BOG from the cold box to the reservoir, characterized by prior to the compression step, pre-heating the BOG to substantially ambient temperatures, by heat exchanging the BOG with said coolant in a first heat exchanger, said coolant prior to the heat exchange having a higher temperature than the BOG, wherein the necessary duty to heat the BOG prior to compression is transferred from the coolant stream, downstream of a coolant compander aftercooler but upstream of the cold box, and wherein a portion of the coolant stream to the BOG pre-heater, at a point between the coolant compander and the pre-heater, is routed into a dedicated flow path in the cold-box before it is mixed with the coolant stream flowing from the pre-heater.

[0012] In one embodiment, the pressure of the reliquefied BOG between the cold box and the reservoir is controlled independently of the BOG compressor discharge pressure and the reservoir pressure, and the amount of vent gas generated and the vent gas composition thus may be controlled.

[0013] It is also provided an apparatus for cooling an LNG boil-off gas (BOG) in a reliquefaction system, comprising a closed-loop coolant circuit for heat exchange between a coolant and the BOG; a BOG compressor having an inlet side fluidly connected to an LNG reservoir; a cold box having a BOG flowpath with a BOG inlet fluidly connected to the BOG compressor outlet side; said BOG flowpath having outlet for substantially re-liquefied BOG, fluidly connected to the reservoir; said cold box further comprising coolant flowpaths for heat exchange between the BOG and the coolant; characterized by a first heat exchanger in the fluid connection between the reservoir and the BOG compressor inlet side, said first heat exchanger having a coolant path fluidly connected to the closed-loop coolant circuit, at a point downstream of the coolant circuit's compander aftercooler but upstream of the coolant flow paths in the cold box, whereby the BOG compressor receives BOG with temperatures near or at the system ambient temperatures a selector valve in the coolant circuit, in a line downstream of the compander aftercooler, and a coolant line at one end connected to a first outlet of the selector valve and at the other end connected to the inlet of the coolant passage of the first heat exchanger, and coolant line, at one end connected to a second outlet of the selector valve and at the other end connected to the inlet of a first coolant passage in the cold box.

[0014] In one embodiment, the invention provides a separator in fluid connection with the cold box outlet and with the reservoir, a first valve in the cold box outlet line and a second valve in a line connected to the reservoir, said separator also comprising a vent line, whereby the pressure in the separator may be controlled, and the amount of vent gas and the vent gas composition thus may be adjusted.

Brief description of the Drawing

[0015]

- 5 Figure 1 is a simplified process flow diagram, illustrating the invention.

Detailed description of preferred embodiments

- 10 **[0016]** The invention will now be described with reference to figure 1, illustrating the novel features of the LNG RS with ambient temperature BOG compression.

- [0017]** The figure shows schematic a cargo tank 74, holding a volume of LNG 72. BOG, evaporating from the LNG, enters a line 1 which is connected to a first heat exchanger H10. In this heat exchanger, the BOG is heated up to near-ambient temperatures, as will be described later. Following this pre-heating, the BOG enters the first stage BOG compressor C11 via line 2. The BOG compressor is shown as a three-stage centrifugal compressor C11, C12, C13, interconnected via lines 3 - 7 via intercoolers H11, H12 and aftercooler H13 as shown in the figure, but other compressor types may be equally applicable. The pre-heating ensures that the heat generated by the compression may be rejected through cooling water in the intercoolers H11, H12 and the aftercooler H13.

- [0018]** Pressurized BOG is then, via a line 8, fed into a second heat exchanger (or "cold box") H20 where it is heat exchanged against a coolant, as will be described later. The coolant is preferably nitrogen (N₂). Following heat exchange, substantially reliquefied BOG exits the cold box H20 via a lines 9, 10 connected to a separator F10. The separator is provided with a vent line 11. A throttling valve V10 is arranged in the lines 9, 10 between the cold box and the separator, for expanding the reliquefied BOG. Following separation, reliquefied BOG is fed into the LNG 72 in the cargo tank 74 via lines 12, 13, as shown in figure 1. A valve V11 is arranged in the lines between the separator F10 and the tank 74, the purpose of which will be described later.

- [0019]** The closed N₂-Brayton cooling cycle is here represented by a 3-stage compressor C21, C22, C23 with intercoolers H21, H22, aftercooler H23, interconnected via lines 51 - 55 as shown in the figure, and a single expander stage E20. (Other cooling cycle constellations, for instance as discussed in Norwegian Patent Application No. 20051315 can also be utilized in this context.) Pressurized coolant (N₂) exits the compressor and the aftercooler H23 via a line 56 connected to a three-way valve V12. The three-way valve V12 is controllable to selectively split the high-pressure N₂ stream flowing in the line 56 into two different streams in respective lines 57, 59, as further detailed below. A first outlet of the three-way valve V12 is connected to a coolant inlet in the first heat exchanger H10 via a line 59. A line 60 connects the coolant outlet of the first heat exchanger H10 with the second heat exchanger's H20 middle section, via line 61, as shown in figure 1. A line 57 connects a second outlet

of the three-way valve V12 to the inlet of a first coolant passage 82 in the second heat exchanger H20 upper section. The first coolant passage 82 outlet is connected via a line 58 to an entry point on the line 60 described above. A line 61 connects this entry point to the inlet of a second coolant passage 84 in the cold box, in the vicinity of the cold box' middle section, as illustrated by figure 1. Coolant flows through the second coolant passage 84 and into an expander E20 via a line 62. The expanded coolant enters the second heat exchanger (cold box) H20 lower section via a line 63 connected to the inlet of a third coolant passage 86 before it exits the heat exchanger and flows back to the compressor C21, C22, C23 via the line 50. The flow split here described as a three-way valve V12 can equally be performed by other flow control configurations, such as normal single line control valves, orifices, etc. The important aspect is that the flow split can be controlled in order to cope with varying BOG flow conditions.

[0020] Generally, the process involves three new features which differ from previously suggested reliquefaction designs:

1. A heat exchanger H10, to ensure that most of the low-temperature duty which can be extracted from the BOG in the ship's vapor header line 1, remains preserved within the reliquefaction system,
2. A BOG compressor C11, C12, C13 working under ambient, or near-ambient conditions, with rejection of its heat of compression H11, H12, H13 to the ambience;
3. A generally higher pressure for the BOG stream 8 entering the main heat exchanger (cold box) H20, compared to the discharge pressure of common BOG compressors, allowing the condensation to take place at a higher temperature level, and at the same time opens the possibilities for controlling the separation pressure in the separator F10 at a level between the cold box outlet pressure in the line 9 and the storage pressure in the cargo tanks 74. This pressure control must be seen in association with flow control through the separator vent line 11 (flow control valve not shown in figure 1). By adjusting the separation pressure, the vent flow, as well as the composition of the condensate which is returned to tanks 74, can be controlled according to the operator preferences. Minimizing the vent gas flow results in higher required reliquefaction power input and vice versa. Adjustments of the separator pressure will therefore allow the operator to select the most favourable conditions for economic optimization of the LNG RS operation.

1. Heat exchanger upstream BOG compressor

[0021] The heat exchanger H10 upstream the BOG compressor C11, C12, C13 is installed to preserve the low-temperature duty in the BOG coming from the tanks

74, within the system. To extract as much low temperature duty as possible from this BOG stream, the BOG temperature should be allowed to increase up to near-ambient temperatures. To preserve the low temperature duty within the system, the duty must be absorbed by another stream in the reliquefaction system, originating at a higher temperature than the BOG stream.

[0022] This other stream will typically be a fraction of the warm high-pressure N₂-stream 59 as shown in figure 1. Other alternatives, such as using the entire N₂-stream (not only a part of it), or the BOG-stream from downstream the BOG compressor's aftercooler are also possible. However, the process of figure 1 will probably be the most beneficial, given the limitations and characteristics of commonly employed equipment for such processes. Consequently, only the process of figure 1, involving a split of the high-pressure N₂-stream 56 downstream the N₂-compressor's aftercooler H23 into two different streams 57, 59, will be discussed next.

[0023] The BOG pre-heater control is based on controlling the coolant flow (N₂) on the secondary side. The energy which is transferred between the compressed N₂ and the BOG in the first heat exchanger H10 (pre-heater) will depend on the BOG flow and temperature, and consequently be a more or less fixed value [kW] as long as the BOG flow is constant. This means that the temperature of the N₂ flow exiting the pre-heater H10 will vary with the N₂ flow rate. As long as the heat transfer area of the pre-heater is large enough, the three-way valve V12 (or equivalent flow split constellations) in the N₂ stream upstream the pre-heater H10 can be used for two different purposes:

A: For thermodynamic optimization of the overall process:

[0024] The freedom represented by the flow split (three-way valve V12) can be used to ensure a very efficient heat exchange (low LMTD [log mean temp difference], and consequently low exergy losses) in the upper parts of the cold box H20. The heating and cooling curves can in theory be designed to be parallel with a constant temperature difference between streams at any temperature in the upper (warm) parts of the cold box.

[0025] Since the Brayton cycle is based on the concept that pressurized N₂ has a higher heat capacity than low pressure N₂, the heating curves can only be made parallel if the high pressure mass flow is smaller than the cold, low pressure flow. The split of the high pressure stream will consequently cause a very efficient heat exchange in the upper parts of the cold box, and since the branch flow also is cooled independently in the BOG pre-heater, the energy penalty which otherwise would have been associated with the mixing of the two high pressure N₂ streams at a lower temperature is reduced to a minimum.

[0026] The flow split will typically be controlled based on the BOG compressor suction temperature.

B: For reducing thermal stress in the cold box to a minimum

[0027] Another benefit of the flow split control made possible by the three-way valve V12 (or alternative flow split constellations), is that the temperature of the high pressure N₂ stream exiting the pre-heater H10 and flowing in the line 60, can be monitored and, if necessary, controlled in order to avoid rapid temperature fluctuations in the flow which is reintroduced to the cold box via the line 61.

[0028] The cold box is normally made in aluminium and is sensitive to thermal stress. By applying a safety control function which changes the flow through the pre-heater based on undesirable conditions, the temperature of all streams entering the cold box can be carefully controlled. This would not have been possible if the pre-heater was a low pressure BOG vs. high pressure BOG heat exchanger, as the high temperature BOG outlet temperature would change synchronously with the fluctuation in the low pressure incoming BOG.

[0029] Normally, the split ratio defining the flows of streams 57 and 59, will be adjusted in order to extract as much low temperature duty as possible from the low temperature BOG. However, this configuration also opens for controlling the split ratio with respect to the temperature of the nitrogen stream 61 entering the cold box' middle section. Doing so, conditions which may expose the main heat exchanger H20 to damaging thermal stresses can easily be eliminated.

[0030] According to an aspect not covered by the present invention and to achieve the optimal heat integration from a thermodynamic point-of-view, the heat exchangers H10 and H20 can be combined in one single multi-pass heat exchanger. However, since the main heat exchanger (cold box) H20 typically will be a plate-fin heat exchanger, which to some extent is sensitive to both rapid temperature fluctuations and large local temperature approaches, it can be feasible to extract some of the heat transfer to an external heat exchanger of a more robust type, as shown at the pre-heater H10 in figure 1.

[0031] The heat exchanger configuration shown in figure 1 will also dampen the temperature fluctuations of the flow 61 entering the main heat exchanger's H20 middle section, since the N₂-coolant stream will be very large compared to the BOG flow. This will ensure a much safer operation with respect to thermal stresses in the cold box.

2. Ambient temperature BOG compressor

[0032] The main incentive for employing ambient temperature BOG compression is the possibility this offers for rejecting heat to the ambience. While today's commonly used BOG compressors preserves the compression heat within the BOG stream, the compression heat can now be delivered to an external source operating at ambient or near ambient temperatures (e.g. cooling wa-

ter).

[0033] Ambient temperature compression also offers other benefits. Since an aftercooler H13 as shown in figure 1 typically will be associated with this system, the temperature of the compressed stream 8 entering the cold box is stabilized relative to the heat rejection source's temperature. After- and intercooling also represent major advantages with respect to operation in recycle and/or anti surge modes, where the external cooling media ensures stable operation, normally without any additional temperature control.

[0034] Ambient temperature BOG compression is especially favourable for LNG vessels where boil-off rates, compositions, temperatures and pressures may vary considerably with the type of voyage (ballast or laden voyages) and cargo. Inter- and aftercooling towards ambient conditions will stabilize the compression conditions and ease capacity control (recycling, etc.)

3. Benefits of selecting a higher pressure ratio

[0035] A "higher" pressure ratio over the BOG compressors C11, C12, C13 will in this context relate to a higher cold box inlet pressure in the line 8 than what is strictly necessary to provide a sufficient differential pressure for forcing the LNG back to the cargo tanks.

[0036] This allows the cryogenic separator F10 to be placed at an intermediate pressure level, typically limited to a zone between two valves V10, V11 as shown in figure 1. The pressure in this zone can then be controlled independently of the BOG compressor discharge pressure and the cargo tank pressure. Accordingly, some of the overall system's capacity control can be performed by pressure adjustments in this region. It will consequently enable the operator or the automated control system to adjust both the amount of vent gas generated as well as the vent gas composition in order to operate under the most economically favourable conditions during all LNG price fluctuations.

[0037] A dedicated line can also be placed in order to bypass the separator under conditions where reliquefied BOG is so much subcooled that the separation pressure otherwise will drop below a defined minimum value.

[0038] The pressure differential between the main heat exchanger H20 and the separator F10 ensures that the separator can be placed more independent of the main heat exchanger. A higher BOG compressor discharge pressure will increase the gain (either in form of a higher adiabatic temperature change or reduced flash gas generation) during the throttling processes down to tank pressure.

[0039] Last, a higher process pressure will increase the heat transfer coefficient in heat the main heat exchanger H20 and ensure that the condensation here will be performed at higher temperatures in order to reduce exergy losses.

[0040] The person skilled in the art will appreciate that the purpose of the three-way valve V12 is to selectively

control the flow split between (i) the line 59 connected to the first heat exchanger H10 and (ii) the line 57 connected to the cold box H20. To this end, the three-way valve V12 described above may be replaced by e.g. a controllable choke valve in the line 60, downstream of the first heat exchanger H10, and a fixed-dimension restriction in the line 57.

Claims

1. A method for cooling an LNG boil-off gas (BOG) stream in a reliquefaction plant, the BOG flowing from a reservoir (74), the method comprising:

- compressing (C11, C12, C13) the BOG;
- heat exchanging the compressed BOG against a coolant in a cold box (H20);
- flowing substantially re-liquefied BOG from the cold box (H20) to the reservoir (74);
- prior to the compression step, pre-heating the BOG to substantially ambient temperatures, by heat exchanging the BOG with said coolant in a first heat exchanger (H10), said coolant prior to the heat exchange having a higher temperature than the BOG, and
- wherein the necessary duty to heat the BOG prior to compression is transferred from the coolant stream, downstream of a coolant compander aftercooler (H23) but upstream of the cold box (H20),

characterized in that a portion of the coolant stream to the first heat exchanger (H10), at a point between the coolant compander aftercooler (H23) and the first heat exchanger (H10), is routed into a dedicated flow path in the cold-box before it is mixed with the coolant stream flowing from the first heat exchanger (H10).

2. The method of claim 1, wherein the pressure of the reliquefied BOG between the cold box and the reservoir is controlled independently of the BOG compressor discharge pressure and the reservoir pressure, and the amount of vent gas generated and the vent gas composition thus may be controlled.
3. An apparatus for cooling an LNG boil-off gas (BOG) in a reliquefaction system, comprising:

- a closed-loop coolant circuit for heat exchange between a coolant and the BOG;
- a BOG compressor (C11, C12, C13) having an inlet side fluidly connected to an LNG reservoir (74);
- a cold box (H20) having a BOG flowpath with a BOG inlet fluidly connected (8) to the BOG compressor outlet side; said BOG flowpath having outlet for substantially re-liquefied BOG, flu-

idly connected (9, 10, 12, 13) to the reservoir;
- said cold box further comprising coolant flow-paths (82, 84, 86) for heat exchange between the BOG and the coolant; and

- a first heat exchanger (H10) in the fluid connection between the reservoir (74) and the BOG compressor inlet side, said first heat exchanger (H10) having a coolant path fluidly connected (59, 60) to the closed-loop coolant circuit, at a point downstream of the coolant circuit's compander aftercooler (H23) but upstream of the coolant flow paths in the cold box, whereby the BOG compressor receives BOG with temperatures near or at the system ambient temperatures, **characterized by**
- a selector valve (V12) in the coolant circuit, in a line (56) downstream of the compander aftercooler (H23), and
- a coolant line (59) at one end connected to a first outlet of the selector valve (V12) and at the other end connected to the inlet of the coolant passage of the first heat exchanger (H10), and
- coolant line (57), at one end connected to a second outlet of the selector valve (V12) and at the other end connected to the inlet of a first coolant passage (82) in the cold box (H20).

4. The apparatus of claim 3, wherein the first heat exchanger (H10) coolant path fluid connection (59, 60) further comprises a coolant line (60) at one end connected to the outlet of the coolant passage of the first heat exchanger (H10) and at the other end connected to a line (58) fluidly connected to the outlet of the second heat exchanger (H20) first coolant passage (82), and wherein said lines (58, 60) are connected (61) to the inlet of a second coolant passage (84) in the second heat exchanger (H20).
5. The apparatus of claim 3, further comprising a separator (F10) in fluid connection (9) with the cold box outlet and with the reservoir (74), a first valve (V10) in the cold box outlet line (9) and a second valve (V11) in a line (12) connected to the reservoir, said separator also comprising a vent line (11), whereby the pressure in the separator may be controlled, and the amount of vent gas and the vent gas composition thus may be adjusted.

Patentansprüche

1. Verfahren zum Abkühlen eines Stromes mit LNG-Boil-Off-Gas (BOG) in einer Verflüssigungsanlage, wobei das BOG aus einem Reservoir (74) fließt, wobei das Verfahren umfasst:

- Komprimieren (C11, C12, C13) des BOG;
- Wärmetauschen des komprimierten BOG ge-

gen ein Kühlmittel in einer Kühlbox (H20);

- Fließen von im Wesentlichen rückverflüssigtem BOG von der Kühlbox (H20) zum Reservoir (74);

- vor dem Schritt der Komprimierung, Vorwärmen des BOG auf im Wesentlichen Umgebungstemperaturen, durch Wärmetauschen des BOG mit dem Kühlmittel in einem ersten Wärmetauscher (H10), wobei das Kühlmittel vor dem Wärmetauschen eine höhere Temperatur hat, als das BOG,

- wobei die nötige Pflicht, um das BOG vor der Komprimierung aufzuwärmen, vom Kühlmittelstrom übertragen wird, stromabwärts von einem Kühlmittelkompander-Nachkühler (H23), jedoch stromaufwärts von der Kühlbox (H20), **dadurch gekennzeichnet, dass**

ein Teil des Kühlmittelstroms zum ersten Wärmetauscher (H10), an einem Punkt zwischen dem Kühlmittelkompander-Nachkühler (H23) und dem ersten Wärmetauscher (H10), in einen zugeordneten Fließpfad in der Kühlbox dirigiert wird, bevor er mit dem Kühlmittelstrom, der vom ersten Wärmetauscher (H10) fließt, gemischt wird.

2. Verfahren nach Anspruch 1, wobei der Druck des verflüssigten BOG zwischen der Kühlbox und dem Reservoir unabhängig vom Ablaufdruck des BOG-Verdichter gesteuert wird und der Reservoirdruck und die Menge an erzeugtem Abgas und die Abgaszusammensetzung dadurch gesteuert werden können.

3. Anordnung zum Abkühlen eines LNG-Boil-Off-Gas (BOG) in einem Verflüssigungssystem, umfassend:

- einen Kühlmittelkreislauf mit geschlossener Schleife zum Wärmetausch zwischen einem Kühlmittel und dem BOG;

- einen BOG-Verdichter (C11, C12, C13) mit einer Eingangsseite, die fluidisch mit einem LNG-Reservoir (74) verbunden ist;

- eine Kühlbox (H20) mit einer BOG-Fließbahn mit einem BOG-Eingang, der fluidisch verbunden (8) ist mit der Auslassseite des BOG-Verdichters; wobei die BOG-Fließbahn einen Auslass hat für im Wesentlichen wieder verflüssigtes BOG, fluidisch verbunden (9, 10, 12, 13) mit dem Reservoir;

- wobei die Kühlbox ferner Kühlmittelfließbahnen (82, 84, 86) zum Wärmetausch zwischen dem BOG und dem Kühlmittel umfasst; und einen ersten Wärmetauscher (H10) in der fluidischen Verbindung zwischen dem Reservoir (74) und der Eingangsseite des BOG-Verdichters, wobei der erste Wärmetauscher (H10) eine Kühlmittelbahn hat, die fluidisch verbunden (59,

60) ist mit dem Kühlmittelkreislauf mit geschlossener Schleife, an einem Punkt stromabwärts vom Kompander-Nachkühler (H23) des Kühlmittelkreislaufes, jedoch stromaufwärts von den Kühlmittelfließbahnen in der Kühlbox, wodurch der BOG-Verdichter BOG mit Temperaturen nahe bei oder zu Umgebungstemperaturen des Systems erhält,

gekennzeichnet durch

- ein Auswahlventil (V12) im Kühlmittelkreislauf, in einer Leitung (56) stromabwärts vom Kompander-Nachkühler (H23), und

- eine Kühlmittelleitung (59), am einen Ende verbunden mit einem ersten Auslass des Auswahlventils (V12) und am anderen Ende verbunden mit dem Einlass des Kühlmitteldurchgangs des ersten Wärmetauschers (H10), und

- eine Kühlmittelleitung (57), am einen Ende verbunden mit einem zweiten Auslass des Auswahlventils (V12) und am anderen Ende verbunden mit dem Einlass eines ersten Kühlmitteldurchgangs (82) in der Kühlbox (H20).

4. Anordnung nach Anspruch 3, wobei die erste Fluidverbindung (59, 60) der Kühlmittelbahn des ersten Wärmetauschers (H10) ferner eine Kühlmittelleitung (60) umfasst, die am einen Ende verbunden ist mit dem Auslass des Kühlmitteldurchgangs des ersten Wärmetauschers (H10) und am anderen Ende verbunden ist mit einer Leitung (58), die fluidisch verbunden ist mit dem Auslass des ersten Kühlmitteldurchgangs (82) des zweiten Wärmetauschers (H20), und wobei die Leitungen (58, 60) verbunden (61) sind mit dem Einlass eines zweiten Kühlmitteldurchgangs (84) im zweiten Wärmetauscher (H20).

5. Anordnung nach Anspruch 3, ferner umfassend einen Separator (F10), der in Fluidverbindung (9) ist mit dem Auslass der Kühlbox und mit dem Reservoir (74), ein erstes Ventil (V10) in der Kühlboxauslassleitung (9) und ein zweites Ventil (V11) in einer Leitung (12), die mit dem Reservoir verbunden ist, wobei der Separator auch eine Abgasleitung (11) umfasst, wobei der Druck im Separator gesteuert werden kann, und die Menge an Abgas und die Abgaszusammensetzung dadurch justiert werden können.

Revendications

1. Procédé de refroidissement d'un flux de gaz d'évaporation de GNL (BOG) dans un système de reliqufaction, le BOG s'écoulant d'un réservoir (74), le procédé comprenant :

- la compression (C11, C12, C13) du BOG ;
- l'échange thermique du BOG comprimé contre un réfrigérant dans une boîte froide (H20) ;

- écoulement du BOG essentiellement reliquéfié à partir de la boîte froide (H20) au réservoir (74) ;
 - avant l'étape de compression, le préchauffage du BOG à des températures essentiellement ambiantes, par l'échange thermique du BOG avec ledit réfrigérant dans un premier échangeur de chaleur (H10), avant l'échange thermique, ledit réfrigérant ayant une température plus élevée que celle du BOG,
 - dans lequel le devoir nécessaire de chauffer le BOG avant la compression est transféré du flux de réfrigérant, en aval d'un refroidisseur final de compandeur de réfrigérant (H23) mais en amont de la boîte froide (H20),

caractérisé en ce qu'une partie du flux de réfrigérant allant au premier échangeur de chaleur (H10), à un point situé entre le refroidisseur final de compandeur de réfrigérant (H23) et le premier échangeur de chaleur (H10), est acheminée dans un trajet d'écoulement dédié dans la boîte froide avant qu'il ne soit mélangé avec le flux de réfrigérant sortant du premier échangeur de chaleur (H10).

2. Procédé selon la revendication 1, dans lequel la pression du BOG reliquéfié entre la boîte froide et le réservoir est commandée indépendamment de la pression de décharge du compresseur BOG et de la pression du réservoir, et la quantité de gaz d'évent générée et la composition de gaz d'évent pouvant ainsi être commandées.

3. Appareil pour refroidir un gaz d'évaporation de GNL (BOG) dans un système de reliquéfaction, comprenant :

- un circuit de réfrigérant en boucle fermée pour un échange thermique entre un réfrigérant et le BOG ;
- un compresseur BOG (C11, C12, C13) ayant un côté entrée relié de manière fluide à un réservoir de GNL (74) ;
- une boîte froide (H20) ayant un trajet d'écoulement de BOG avec une entrée BOG reliée de manière fluide (8) au côté sortie du compresseur BOG ; ledit trajet d'écoulement de BOG ayant une sortie pour le BOG essentiellement reliquéfié, reliée de manière fluide (9, 10, 12, 13) au réservoir ;
- ladite boîte froide comprenant en outre des trajets d'écoulement de réfrigérant (82, 84, 86) pour un échange thermique entre le BOG et le réfrigérant ; et un premier échangeur de chaleur (H10) dans le raccord fluide entre le réservoir (74) et le côté entrée du compresseur BOG, ledit premier échangeur de chaleur (H10) ayant un trajet de réfrigérant relié de manière fluide (59, 60) au circuit de réfrigérant en boucle fermée,

situé à un point en aval du refroidisseur final de compandeur de réfrigérant (H23), mais en amont des trajets d'écoulement du réfrigérant dans la boîte froide,

le compresseur BOG recevant le BOG à des températures proches ou égales aux températures ambiantes du système,

caractérisé par

- une vanne de sélection (V12) dans le circuit de réfrigérant, dans une conduite (56) en aval du refroidisseur final de compandeur (H23), et
- une conduite de réfrigérant (59) à une extrémité raccordée à une première sortie de la vanne de sélection (V12) et à l'autre extrémité raccordée à l'entrée du passage de réfrigérant du premier échangeur de chaleur (H10), et
- une conduite de réfrigérant (57) à une extrémité raccordée à une deuxième sortie du sélecteur vanne (V12) et à l'autre extrémité raccordée à l'entrée d'un premier passage de réfrigérant (82) dans la boîte froide (H20).

4. Appareil selon la revendication 3, dans lequel le raccord fluide de trajet de réfrigérant (59, 60) du premier échangeur de chaleur (H10) comprend en outre une conduite de réfrigérant (60) à une extrémité raccordée à la sortie du passage de réfrigérant du premier échangeur de chaleur (H10) et à l'autre extrémité raccordée à une conduite (58) reliée de manière fluide à la sortie du premier passage de réfrigérant (82) du deuxième échangeur de chaleur (H20), et dans lequel lesdites conduites (58, 60) sont raccordées (61) à l'entrée d'un deuxième passage de réfrigérant (84) dans le deuxième échangeur de chaleur (H20).

5. Appareil selon la revendication 3, comprenant en outre un séparateur (F10) relié de manière fluide (9) à la sortie de la boîte froide et au réservoir (74), une première vanne (V10) dans la conduite de sortie de la boîte froide (9) et une deuxième vanne (V11) dans une conduite (12) reliée au réservoir, ledit séparateur comprenant également une tuyauterie de ventilation (11), la pression dans le séparateur pouvant être commandée, et la quantité de gaz d'évent et la composition de gaz d'évent pouvant ainsi être ajustées.

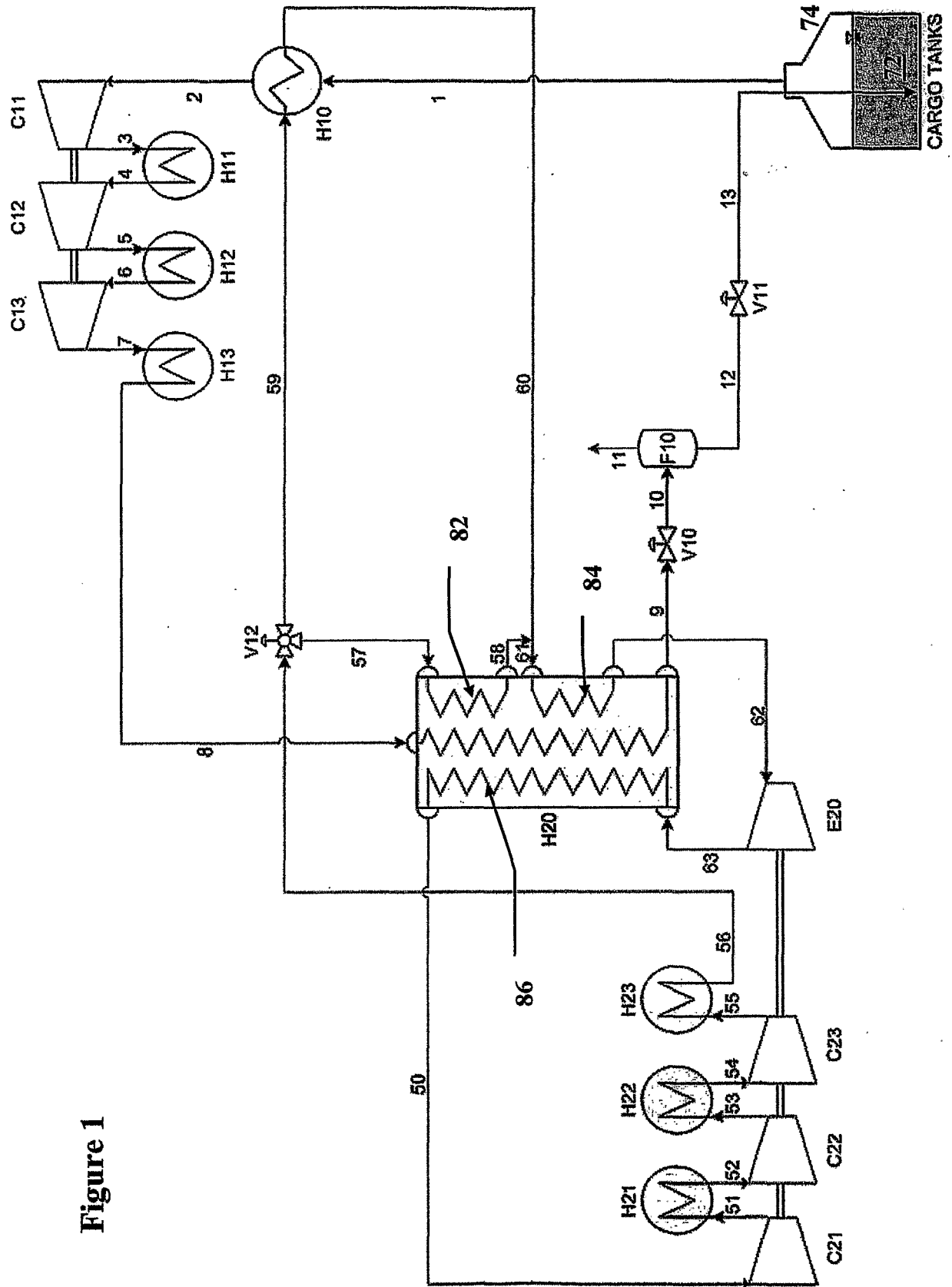


Figure 1

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- US 20030182947 A [0001]
- US 2003182947 A [0004]
- WO 03081154 A1 [0005]
- NO 20051315 [0006] [0019]