



(11) **EP 1 860 393 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
28.11.2007 Bulletin 2007/48

(51) Int Cl.:
F25J 1/02 (2006.01) **F17C 9/00** (2006.01)

(21) Application number: **06352012.6**

(22) Date of filing: **23.05.2006**

(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 NL PL PT RO SE SI
SK TR**
Designated Extension States:
AL BA HR MK YU

(71) Applicant: **Cryostar SAS**
68220 Hesingue (FR)

(72) Inventor: **Fuchs, Vincent**
68870 Bartenheim (FR)

(74) Representative: **Morelle, Guy Georges Alain**
Cabinet Morelle & Bardou
9, Avenue de l'Europe- BP 72253
31522 Ramonville Saint Agne Cedex (FR)

(54) **Method and apparatus for the reliquefaction of a vapour**

(57) Vapour boiled off from a liquefied natural gas storage tank (10) is compressed in vapour compression stages (40) and (42). The resulting compressed vapour is condensed in a condenser (46) and the condensate returned to the tank (10). The condenser (46) is cooled by means of a working fluid, for example nitrogen, flowing in a Brayton cycle (60). The Brayton cycle includes a heat exchanger (86) which removes heat of compression from the compressed natural gas vapour upstream of its passage through the condenser (46). In addition a part of

the working fluid is withdrawn from a region of the Brayton cycle (60) intermediate the working fluid outlet from the condenser (46) and the working fluid inlet to the heat exchanger (86) and the withdrawn working fluid flows through another heat exchanger (88) in which it removes heat of compression from the natural gas vapour intermediate the compression stage (40) and the compression stage (42). The withdrawn working fluid is returned to the Brayton cycle (60).

EP 1 860 393 A1

Description

[0001] This invention relates to a method and apparatus for the reliquefaction of a vapour, particularly a method and apparatus which are operable on board ship to reliquefy natural gas vapour.

[0002] Natural gas is conventionally transported over large distances in liquefied state. For example, ocean going tankers are used to convey liquefied natural gas from a first location in which the natural gas is liquefied to a second location in which it is vaporised and sent to a gas distribution system. Since natural gas liquefies at cryogenic temperatures, i.e. temperatures below -100°C, there will be continuous boil-off of the liquefied natural gas in any practical storage system. Accordingly, apparatus needs to be provided in order to reliquefy the boiled-off vapour. In such an apparatus a refrigeration cycle is performed comprising compressing a working fluid in a plurality of compressors, cooling the compressed working fluid by indirect heat exchange, expanding the working fluid, and warming the expanded working fluid in indirect heat exchange with the compressed working fluid, and returning the warmed working fluid to one of the compressors. The natural gas vapour, downstream of a compression stage, is at least partially condensed by indirect heat exchange with the working fluid being warmed. One example of an apparatus for performing such a refrigerant method is disclosed in US patent 3 857 245.

[0003] According to US patent 3 857 245 the working fluid is derived from the natural gas itself and therefore an open refrigeration cycle is operated. The expansion of the working fluid is performed by a valve. Partially condensed natural gas is obtained. The partially condensed natural gas is separated into a liquid phase which is returned to storage and a vapour phase which is mixed with natural gas being sent to a burner for combustion. The working fluid is both warmed and cooled in the same heat exchanger so that only one heat exchanger is required. The heat exchanger is located on a first skid-mounted platform and the working fluid compressors on a second skid-mounted platform.

[0004] Nowadays, it is preferred to employ a non-combustible gas as the working fluid. Further, in order to reduce the work of compression that needs to be supplied externally, it is preferred to employ an expansion turbine rather than a valve in order to expand the working fluid.

[0005] An example of an apparatus which embodies both these improvements is given in WO-A-98/43029. Now two heat exchangers are used, one to warm the working fluid in heat exchange with the compressed natural gas vapour to be partially condensed, and the other to cool the compressed working fluid.

[0006] WO-A-98/43029 points out that incomplete condensation of the natural gas vapour reduces the power consumed in the refrigeration cycle (in comparison with complete condensation) and suggests that the residual vapour - which is relatively rich in nitrogen - should

be vented to the atmosphere. Indeed, the partial condensation disclosed in WO-A-98/43029 follows well known thermodynamic principles which dictate that the condensate yield is purely a function of the pressure and temperature at which the condensation occurs.

[0007] Typically, the liquefied natural gas may be stored at a pressure a little above atmospheric pressure and the boil-off vapour may be partially condensed at a pressure of 4 bar. The resulting partially condensed mixture is typically flashed through an expansion valve into a phase separator to enable the vapour to be vented at atmospheric pressure. Even if the liquid phase entering the expansion valve contains as much as 10 mole per cent of nitrogen at 4 bar, the resulting vapour phase at 1 bar still contains in the order of 50% by volume of methane. In consequence, in a typical operation, some 3000 to 5000 kg of methane may need to be vented daily from the phase separator. Since methane is recognised as a greenhouse gas such a practice would be environmentally unacceptable.

[0008] Another problem associated with the operation of the apparatus according to WO-A-98/43029, is that there are considerable thermodynamic inefficiencies caused by a mismatch between, on the one hand, the temperature and enthalpy of the compressed natural gas and, on the other hand, the temperature and enthalpy of the working fluid.

[0009] EP-A-1 132 698 discloses a method that mitigates the problems that are caused when vapour is returned with condensed natural gas to a liquefied natural gas (LNG) storage tank.

[0010] In the method according to EP-A-1 132 698 the boiled off vapour and/or the natural gas condensate are mixed with liquefied natural gas taken from storage.

[0011] Since the nitrogen mole fraction in the liquefied natural gas is less than the nitrogen mole fraction in the boiled-off vapour and even less than that in flash gas formed by the expansion through the valve of the condensed boil-off vapour, dilution of the boiled-off vapour with the liquefied natural gas either upstream or downstream of the condenser, or both, tends to dampen swings in the composition of the vapour phase in the storage tank that would otherwise occur without the mixing of the boiled off vapour or natural gas condensate with the liquefied natural gas from storage.

[0012] The method according to EP-A-1 132 698 does not however greatly enhance the overall thermodynamic efficiency.

[0013] According to the present invention there is provided a method of reliquefying vapour boiled off from at least one volume of liquefied natural gas held in at least one storage tank, comprising compressing the vapour in first and second vapour compression stages in series, condensing the compressed vapour in a condenser by heat exchange with a working fluid flowing in a main endless working fluid cycle, and returning at least some of the resulting condensate to the said storage tank, wherein in the main working fluid cycle the working fluid is, in

sequence, compressed in at least one working fluid compressor, cooled in a first heat exchanger, expanded in an expansion turbine, employed in the condenser to perform the condensation of the natural gas vapour, warmed in the said first heat exchanger in heat exchange with the working fluid being cooled and returned to the said working fluid compressor, characterised in that in the main working fluid cycle intermediate the passage of the working fluid through the condenser and its passage through the first heat exchanger, the working fluid is employed to precool in a second heat exchanger the compressed natural gas vapour downstream of the second vapour compression stage but upstream of the condenser, and in that a flow of working fluid is diverted from a region of the main working fluid cycle where the working fluid is flowing from the condenser to the second heat exchanger and is passed through at least one third heat exchanger so as to cool the natural gas vapour intermediate the first and second vapour compression stages, the diverted working fluid being returned to the main working fluid cycle at a region where the working fluid is flowing from the second heat exchanger to the first heat exchanger.

[0014] The invention also provides apparatus for reliquefying natural gas vapour comprising at least one storage tank for holding at least one volume of liquefied natural gas, first and second vapour compression stages in series for compressing boiled-off natural gas vapour communicating with at least one vapour space in the said storage tank, a condenser for condensing the compressed vapour having a natural gas inlet communicating with the second vapour compression stage and an outlet communicating with the said storage tank, wherein the condenser is arranged so as to be cooled, in use, by a working fluid, the condenser forming part of an endless main working fluid cycle comprising, in sequence, (a) at least one working fluid compressor for compressing a flow of the working fluid, (b) a cooling path through a first heat exchanger for cooling the working fluid flow, (c) an expansion turbine for expanding the flow of working fluid, (d) the condenser, (e) a warming path through the first heat exchanger for warming the working fluid, and (f) an inlet to the said working fluid compressor, characterised in that the main working fluid cycle comprises a second heat exchanger for cooling the natural gas by heat exchange with the working fluid, the second heat exchanger having a natural gas vapour path therethrough intermediate the second vapour compression stage and the condenser and a working fluid path therethrough intermediate the working fluid outlet from the condenser and the inlet to the warming path through the first heat exchanger, and in that there is a third heat exchanger for cooling the natural gas vapour intermediate the first and second natural gas vapour compression stages by heat exchange with working fluid diverted from the main working fluid cycle, the third heat exchanger having a working fluid path therethrough communicating at its inlet with a region of the working fluid cycle intermediate the working fluid outlet from the condenser and the working fluid inlet to

the second heat exchanger and at its outlet with a region of the working fluid cycle intermediate the working fluid outlet from the second heat exchanger and the inlet to the warming path through the first heat exchanger.

[0015] The method and apparatus according to the invention are able to achieve improved thermodynamic efficiency of operation in comparison with the corresponding methods and apparatuses disclosed in the prior documents mentioned above. We attribute the improved thermodynamic efficiency to the integration of the working fluid cycle and the natural gas condensation not only in the condenser but also in the second and third heat exchangers. The improvement in thermodynamic efficiency can be exploited by means of a reduced power consumption.

[0016] Preferably the proportion of the working fluid that is diverted from the main working fluid cycle to the third heat exchanger is controlled in response to the temperature at the inlet to the second vapour compression stage.

[0017] Preferably when the said storage tank is fully laden with liquefied natural gas, the condenser is operated such that sub-cooled liquefied natural gas exits from it. Sometimes, however, when the said storage tank contains only a relatively small amount of liquefied natural gas return of the condensate to the tank has the effect of enriching the boiled-off vapour in nitrogen. In consequence the vapour presented to the condenser for condensation may contain an excess of nitrogen with the consequence that not only is the condensate not sub-cooled but it is not even fully condensed. In such circumstances, or if the storage tank contains a liquefied natural gas having a high nitrogen content, for example, one that gives a boil-off gas containing 20 to 40% by volume of nitrogen, the condensate, which contains uncondensed vapour, is flashed into a phase separator, the resultant liquid phase being returned to the storage tank and the resultant vapour phase being sent to the ship's engines (in the case of shipboard use if the engines are powered by natural gas) or is burnt and vented to the atmosphere.

[0018] The first and second vapour compression stages are preferably driven by a single plural speed motor.

[0019] Preferably the vapour upstream of the first vapour compression stage is precooled by having mixed therewith a stream of condensed natural gas taken from the condenser. Preferably the flow rate of the stream of condensed natural gas vapour is controlled in response to the temperature at the inlet to the first compression stage.

[0020] The method and apparatus according to the invention will now be described by way of example with reference to the accompanying drawing, in which:

Figure 1 is a schematic flow diagram of a shipboard installation for the storage of liquefied natural gas (LNG).

[0021] The drawing is not to scale.

[0022] Referring to the drawing, the five thermally-insulated storage tanks 2, 4, 6, 8 and 10 are provided in the hull of a ship or other sea-going vessel (not shown). Two or more of the storage tanks 2, 4, 6, 8 and 10 are provided with a submerged orifice pipe 12 located in its bottom region through which LNG is introduced. For reasons of ease of illustration, the orifice pipes in the tanks 2, 4 and 6 are not shown in the drawing. If only some of the storage tanks are provided with submerged orifice pipes, redistribution of returning LNG to tanks not so provided is by operation of liquid pumps (not shown). The orifice pipe 12 is in normal operation submerged in a volume 16 of LNG. In each of the tanks 2, 4, 6, 8 and 10 there is a vapour space 18 above the volume 16 of LNG therein.

[0023] Although the storage tanks 2, 4, 6, 8 and 10 are thermally insulated, because LNG has a boiling point at normal pressures substantially below ambient temperature there is a continuous evaporation of the LNG in each of the storage tanks 2, 4, 6, 8 and 10. Each of the tanks has a top outlet 22 for vapour which communicates with a boiled-off gas header 24. Extending from the header 24 is a main pipeline 26 for the boiled-off gas. Located in the pipeline 26 is a mixer 28, in which, in operation, the vapour may be mixed with condensed LNG from a downstream part of the installation. In operation, the condensed LNG evaporates in the boiled-off gas and thereby reduces the temperature of this gas. A sensor 27 is provided downstream of the mixer and generates signals representative of the temperature at the inlet to a first compression stage 40, which signals are relayed to a valve controller 30, which in turn controls the setting of the flow-control valve 32 in a LNG condensate pipeline 34 that terminates in a spray nozzle 36 within the mixer 28. The mixer 28 may thus be operated so as to provide natural gas at a chosen essentially constant cryogenic temperature below, say, minus 100°C to the first compression stage 40.

[0024] The boiled-off gas flows from the mixer 28 into the first compression stage. The outlet of the first compression stage 40 indirectly communicates with the inlet of a second compression stage 42. The compression stages 40 and 42 are typically driven by a single electric motor 44 through, if desired, an integral gearbox 45.

[0025] The motor 44 is typically able to be operated at two different speeds.

[0026] Resulting compressed gas is supplied from the second compression stage 42 to a condenser 46, typically in the form of a plate fin or spirally wound heat exchanger, in which it is condensed and once condensed subjected to subcooling. The resulting sub-cooled condensate flows from the condenser 46 along a pipeline 48 to a condensate return header 50 which feeds the orifice pipes 12 in the bottom regions of the tanks 8 and 10, or if each tank is equipped with the orifice pipe 12, to the tanks 2, 4, 6, 8 and 10.

[0027] Cooling for the condenser 46 is provided by a working or heat exchange fluid such as nitrogen flowing

at a first pressure in an essentially closed refrigeration cycle 60 such as a Brayton cycle.

[0028] In the Brayton cycle 60 nitrogen passing out of the condenser 46 is warmed in heat exchange with returning compressed nitrogen at a second pressure higher than the first in a gas-to-gas heat exchanger 62. The resulting warmed nitrogen flows to a compressor 64 which typically comprises three compression stages 66, 68 and 70 all having rotors (not shown) mounted on an integral gearbox (not shown) or on the same shaft 72 able to be driven by a motor 74 through a gearbox 75. A first intercooler 78 is located downstream of the outlet from the first compression stage 66 and upstream of the inlet to the second compression stage 68. A second intercooler 80 is located downstream of the outlet from the second compression stage 68 and upstream of the inlet to the third compression stage 70. An aftercooler 82 is located downstream of the outlet from the third compression stage 70. The intercoolers 78 and 80 and the aftercooler 82 are typically all cooled by water and are operated so as to remove the heat of compression from the circulating nitrogen in operation of the Brayton cycle. The resulting aftercooled compressed nitrogen flow passes through the heat exchanger 63 as the previously mentioned returning cold nitrogen stream. The compressed nitrogen stream is thus cooled to a lower temperature in the heat exchanger 62. The compressed cooled nitrogen flow passes to an expansion turbine 84 where it is expanded with the performance of extra work. The expansion turbine 84 is typically mounted on the same integral gearbox (not shown) or on the same shaft as the compression stages 66, 68 and 70. The expansion turbine 84 thus helps to drive the compression stages 66, 68 and 70. The expansion of the nitrogen in the turbine 84 generates the refrigeration necessary for the condensation of the natural gas vapour in the condenser 46. The nitrogen thus continuously passes through an endless circuit.

[0029] A particular feature of the Brayton cycle 60 illustrated in the drawing is that the nitrogen does not pass directly from the condenser 46 to the heat exchanger 62. Instead it passes through a second gas-to-gas counter-current heat exchanger 86. The purpose of this heat exchanger is to pre-cool the natural gas to a temperature close to its condensation temperature upstream of entering the condenser 46. During typical operating conditions when the tanks 2, 4, 6, 8 and 10 are fully laden with LNG the natural gas is consequently not only liquefied but also sub-cooled in the condenser 46. The sub-cooling of the liquefied natural gas keeps down the formation of flash gas when the LNG is returned to the tanks.

[0030] A further feature of the particular form of Brayton cycle 60 shown in the drawings is that a part of the nitrogen is withdrawn from a region of the Brayton cycle downstream of the outlet from the condenser 46 but upstream of the inlet to the second heat exchanger 86 and flows through a third heat exchanger 88 which is located downstream of the first natural gas compression stage 40 but upstream of the second natural gas compression

stage 42 and thus serves to remove the heat of compression generated in the natural gas by operation of the first compression stage 40. As a result, the nitrogen passing through the third heat exchanger 88 is warmed. The warmed nitrogen flow is returned to the Brayton cycle 60 at a region downstream of the outlet from the second heat exchanger 86 but upstream of the inlet to the warming passages through the first heat exchanger 62. Typically, a control valve 90 controls the rate of flow of nitrogen working fluid through the third heat exchanger in response to a temperature sensor (not shown) at the inlet to the second natural gas compression stage 42. In a typical arrangement, the control valve 90 operates to maintain a constant temperature at the inlet to the second natural gas compression stage 42.

[0031] Not all the natural gas that is liquefied in the condenser 46 is typically returned via the pipeline 50 to the tanks 2, 4, 6, 8 and 10. A portion of the condensate is sent via the pipeline 34 to the mixer 28 so as to pre-cool the natural gas upstream of the first compression stage 40.

[0032] In operation, there are various ways of operating the apparatus shown in the drawing according to how laden with LNG the tanks 2, 4, 6, 8 and 10 are. When these tanks are fully laden, the temperature at the inlet to the first natural gas compression stage 40 is typically in the order of minus 100°C or even lower. The pressure at the inlet is typically a little above 1 bar. The natural gas typically leaves the first compression stage at a temperature of minus 65°C and a pressure in the order of 2 bar. The gas is typically cooled in the heat exchanger to a temperature in the order of minus 130°C and enters the second natural gas compression stage at this temperature. The natural gas typically leaves the second compression stage 42 at a pressure in the order of 5 bar and a temperature of about minus 75°C. The natural gas is cooled in the second heat exchanger to a temperature at which it will begin to condense. The exact value of this temperature will depend on the composition of the natural gas. The greater the mole fraction of nitrogen in the natural gas, the lower will be the temperature at which it starts to condense. Because the condenser 46 is not required to desuperheat the natural gas in normal operation, more efficient heat exchange is made possible than in previously known cycles in which the corresponding condenser has been required both to desuperheat and to condense the natural gas. As a result of the intercooling, desuperheating and separate condensing with sub-cooling, the power consumption of the refrigeration cycle is reduced.

[0033] As previously stated, the natural gas leaves the condenser 46 as a sub-cooled liquid. Typically, its exit temperature is in the order of minus 165°C depending on the composition of the natural gas. One of the advantages of such a low exit temperature is that relatively little, if any, flash gas is formed on reintroduction of the LNG into the tanks 2, 4, 6, 8 and 10 through the orifice pipes 12. Moreover, when the tanks are fully laden, any flash

gas that is formed may be dissolved or condensed in the liquid before it reaches the surface.

[0034] During normal operation when the tanks are fully laden the expansion turbine 84 typically has an inlet temperature in the order of minus 104°C, an outlet temperature in the order of minus 168°C, and an outlet pressure in the order of 10 bar. If the composition of the natural gas is, say, 8.5% by volume of nitrogen and 91.5% by volume of methane, this temperature is sufficiently low for the condensate produced in the condenser 46 to have a desired degree of sub-cooling. Sometimes, however, the ship in which the tanks 2, 4, 6, 8 and 10 are located is required to transport sufficiently less than the maximum amount of LNG for the liquid head in the tanks not to be sufficient to prevent flashing of condensate returned through the orifice pipes 12 or to ensure complete dissolution of fine bubbles of flash gas that are formed in the volumes 16 of LNG. As a result, the vapour that flows from the tanks 2, 4, 6, 8 and 10 to the first compression stage 40 is enriched in nitrogen. As a consequence, its condensation temperature at the outlet pressure of the second natural gas vapour compression stage 42 falls. Indeed, when the tanks are relatively lightly laden with LNG the degree of enrichment may become so great that the condenser 46 no longer fully condenses the vapour. In this case, instead of being passed to the conduit 50, the mixture of condensate and uncondensed vapour may be selectively directed through a valve 100 into a phase separator 102. Liquid is withdrawn from the bottom of the phase separator 102 and sent to the conduit 50. Vapour passes from the phase separator 102 to a vent line 104 which leads through a heater 106 to a gas combustion unit 108 so that the natural gas content of the vapour may be burned and the resulting combustion gases vented to the atmosphere.

[0035] The minimum and maximum flows of natural gas vapour in operation of the apparatus shown in the drawing can vary widely. It is therefore typically preferred to employ two sets of first and second natural gas compression stages 40 and 42, the two sets being in parallel with one another. Thus, there are typically two third heat exchangers 88 in parallel with one another. Whether one or both sets are used depends on the rate of vaporisation of the natural gas in the tanks 2, 4, 6, 8 and 10. Similarly, they may be two or more sets of nitrogen compression stages 66, 68 and 70 in parallel, and two or more expansion turbines 84 in parallel.

Claims

1. A method of reliquefying vapour boiled off from at least one volume of liquefied natural gas held in at least one storage tank, comprising compressing the vapour in first and second vapour compression stages in series, condensing the compressed vapour in a condenser by heat exchange with a working fluid flowing in a main endless refrigeration cycle, and re-

turning at least some of the resulting condensate to the said storage tank, wherein in the main working fluid cycle the working fluid is, in sequence, compressed in at least one working fluid compressor, cooled in a first heat exchanger, expanded in an expansion turbine, employed in the condenser to perform the condensation of the natural gas vapour, warmed in the said first heat exchanger in heat exchange with the working fluid being cooled and returned to the said working fluid compressor, **characterised in that** in the main working fluid cycle intermediate the passage of the working fluid through the condenser and its passage through the first heat exchanger, the working fluid is employed to pre-cool in a second heat exchanger the compressed natural gas vapour downstream of the second vapour compression stage but upstream of the condenser, and **in that** a flow of working fluid is diverted from a region of the main working fluid cycle where the working fluid is flowing from the condenser to the second heat exchanger and is passed through at least one third heat exchanger so as to cool the natural gas vapour intermediate the first and second vapour compression stages, the diverted working fluid being returned to the main working fluid cycle at a region where the working fluid is flowing from the second heat exchanger to the first heat exchanger.

2. A method according to claim 1, in which the proportion of the working fluid that is diverted from the main working fluid cycle to the third heat exchanger is controlled in response to the temperature at the inlet to the second vapour compression stage.
3. A method according to claim 1 or claim 2, wherein when the said storage tank is fully laden with liquefied natural gas the condenser is operated such that sub-cooled liquefied natural gas exits from it.
4. A method according to any one of the preceding claims, in which the vapour upstream of the first vapour compression stage is pre-cooled by having mixed therewith a stream of condensed natural gas taken from the condenser.
5. A method according to claim 4, in which the flow rate of the stream of condensed vapour is controlled in response to the temperature at the inlet to the first compression stage.
6. Apparatus for reliquefying natural gas vapour comprising at least one storage tank for holding at least one volume of liquefied natural gas, first and second vapour compression stages in series for compressing boiled-off natural gas vapour communicating with at least one vapour space in the said storage tank, a condenser for condensing the compressed vapour having a natural gas inlet communicating with a sec-

ond vapour compression stage and an outlet communicating with the said storage tank, wherein the condenser is arranged so as to be cooled, in use, by a working fluid, the condenser forming part of an endless main working fluid cycle comprising, in sequence, (a) at least one working fluid compressor for compressing a flow of the working fluid, (b) a cooling path through a first heat exchanger for cooling the working fluid flow, (c) an expansion turbine for expanding the flow of working fluid, (d) the condenser, (e) a warming path through the first heat exchanger for warming the working fluid, and (f) an inlet to the said working fluid compressor, **characterised in that** the main working fluid cycle comprises the second heat exchanger for cooling the natural gas by heat exchange with the working fluid, the second heat exchanger having a natural gas vapour path therethrough intermediate the second vapour compression stage and the condenser and a working fluid path therethrough intermediate the working fluid outlet from the condenser and the inlet to the warming path through the first heat exchanger, and **in that** there is a third heat exchanger for cooling the natural gas vapour intermediate the first and second natural gas vapour compression stages by heat exchange with working fluid diverted from the main working fluid cycle, the third heat exchanger having a working fluid path therethrough communicating at its inlet with a region of the working fluid cycle intermediate the working fluid outlet from the condenser and the working fluid inlet to the second heat exchanger and at its outlet with a region of the working fluid cycle intermediate the working fluid outlet from the second heat exchanger and the inlet to the warming path through the first heat exchanger.

7. Apparatus according to claim 6, wherein there is a valve for controlling the proportion of the working fluid that is diverted from the main working fluid cycle to the third heat exchanger in response to the temperature at the inlet to the second vapour compression stage.
8. Apparatus according to claim 6 or claim 7, in which the first and second vapour compression stages are driven by a single plural speed motor.
9. Apparatus according to any one of claims 6 to 8, additionally including a mixer upstream of the first vapour compression stage in which the natural gas vapour is able to be cooled, the mixer having an inlet for condensed natural gas communicating with the condenser.
10. Apparatus according to claim 9, including a valve for controlling the flow of condensate to the mixer and operable to maintain constant the temperature at the inlet to the first compression stage.

11. Apparatus according to any one of claims 6 to 10, wherein an outlet for condensate from the condenser is able selectively to be placed through an expansion valve in communication with a phase separator having an outlet for returning liquid to the storage tank and an outlet for passing vapour to a combustion unit.

5

10

15

20

25

30

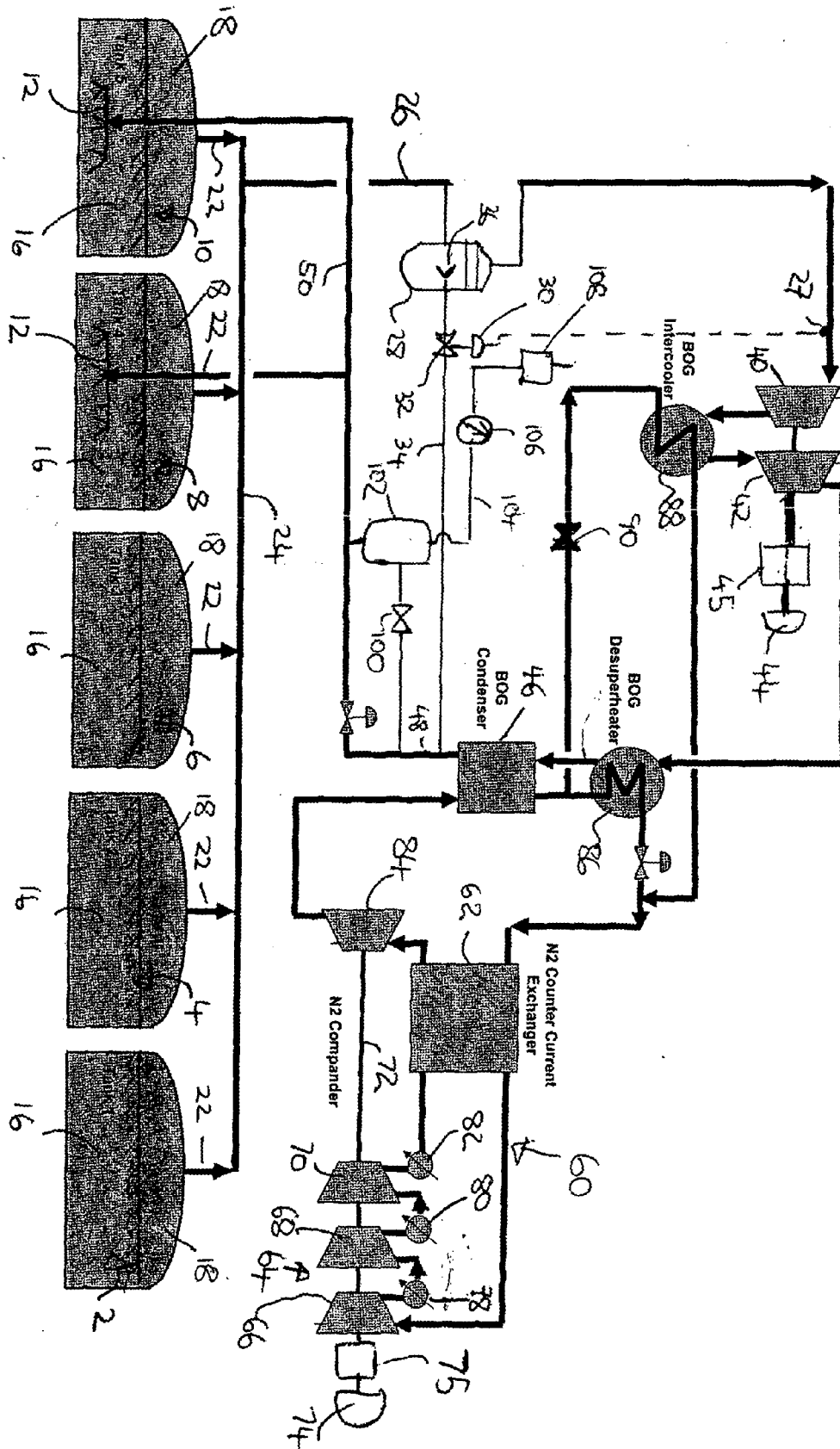
35

40

45

50

55





European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 06 35 2012

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	WO 2005/047761 A (HAMWORTHY KSE GAS SYSTEMS AS [NO]; RUMMELHOFF CARL JOERGEN [NO]) 26 May 2005 (2005-05-26) * figures 1,2 *	1,4-6, 8-11	INV. F25J1/02 F17C9/00
A	US 3 874 185 A (ETZBACH VOLKER) 1 April 1975 (1975-04-01) * figure 1 *	1,6,11	
D,A	EP 1 132 698 A1 (CRYOSTAR FRANCE SA [FR] CRYOSTAR SAS [FR]) 12 September 2001 (2001-09-12) * the whole document *	4,8-10	
A	WO 2005/071333 A (HAMWORTHY KSE GAS SYSTEMS AS [NO]; RUMMELHOFF CARL JOERGEN [NO]) 4 August 2005 (2005-08-04) * figures 1,2 *	4,5,9,10	
A	EP 1 120 615 A2 (CRYOSTAR FRANCE SA [FR] CRYOSTAR SAS [FR]) 1 August 2001 (2001-08-01) * figure *	8,11	TECHNICAL FIELDS SEARCHED (IPC) F25J F17C
A	WO 2005/040667 A (MOSS MARITIME AS [NO]; CHRISTIANSEN PER ERIK [NO]; SOERENSEN ROY INGE) 6 May 2005 (2005-05-06) * figure *	11	
E	WO 2006/098630 A (HAMWORTHY KSE GAS SYSTEMS AS [NO]; RUMMELHOFF CARL JOERGEN [NO]; HAUKE) 21 September 2006 (2006-09-21) * figures 6,8 *	1,6	
E	WO 2006/078104 A (DAEWOO SHIPBUILDING & MARINE [KR]) 27 July 2006 (2006-07-27) * figure 1 *	4,5,9-11	
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 2 November 2006	Examiner Göritz, Dirk
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

1
EPO FORM 1503 03.92 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 06 35 2012

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

02-11-2006

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
WO 2005047761	A	26-05-2005	EP 1697679 A1	06-09-2006

US 3874185	A	01-04-1975	FR 2210752 A1	12-07-1974
			GB 1395270 A	21-05-1975
			IT 1002519 B	20-05-1976
			JP 1089433 C	23-03-1982
			JP 49090277 A	28-08-1974
			JP 56032539 B	28-07-1981
			NL 7315311 A	20-06-1974
			NO 133287 B	29-12-1975
			SE 395315 B	08-08-1977

EP 1132698	A1	12-09-2001	AT 330194 T	15-07-2006

WO 2005071333	A	04-08-2005	NONE	

EP 1120615	A2	01-08-2001	AT 340346 T	15-10-2006
			CN 1320540 A	07-11-2001
			JP 2001248977 A	14-09-2001
			US 2001018833 A1	06-09-2001

WO 2005040667	A	06-05-2005	EP 1682814 A1	26-07-2006

WO 2006098630	A	21-09-2006	NONE	

WO 2006078104	A	27-07-2006	FR 2880942 A1	21-07-2006
			JP 2006200735 A	03-08-2006
			US 2006156758 A1	20-07-2006

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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 3857245 A [0002] [0003]
- WO 9843029 A [0005] [0006] [0006] [0008]
- EP 1132698 A [0009] [0010] [0012]