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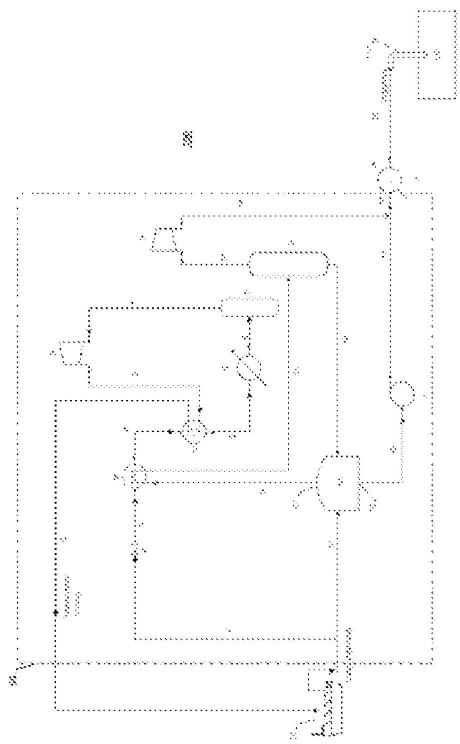
(54) Title **SYSTEM AND METHOD FOR OFFLOADING LCO2 FROM A SHIP TO AN INTERMEDIATE STORAGE AT AN LCO2 RECEIVING TERMINAL**

(57) Abstract

A system 50 for offloading LCO2 from an LCO2 carrier ship 30 to an intermediate LCO2 storage tank 40 at an LCO2 receiving terminal 100 connected to a long term LCO2 storage reservoir 120 is disclosed, which system avoids cross-contamination from cargo of one ship to another, wherein a slip stream of LCO2 withdrawn from a main stream of LCO2 being offloaded to the terminal 100 is vaporised and returned to the LCO2 carrier ship 30, and the vaporisation is used to providing cooling for complete or partial reliquefaction of a boil-off gas stream withdrawn from the intermediate LCO2 storage tank 40, and wherein a resulting reliquefied fraction is returned to the intermediate LCO2 storage tank 40. A corresponding method is also disclosed.



SYSTEM AND METHOD FOR OFFLOADING LCO_2 FROM A SHIP TO AN INTERMEDIATE STORAGE AT AN LCO_2 RECEIVING TERMINAL

FIELD OF THE INVENTION

The present invention generally relates to Cabon Capture and Storage (CCS) technology, and more particularly to a system for offloading liquid CO_2 (LCO_2) from an LCO_2 carrier ship to an intermediate LCO_2 storage tank at an LCO_2 receiving terminal connected to a long term LCO_2 storage reservoir, wherein cross-contamination from cargo of one ship to another, via common intermediate storage tanks, can be avoided. The invention also relates to a corresponding method. The invention uses a slip stream of LCO_2 withdrawn from a main stream of LCO_2 being offloaded to the terminal which is vaporised and returned to the LCO_2 carrier ship, and the vaporisation is used to providing cooling for complete or partial reliquefaction of a boil-off gas stream withdrawn from the intermediate LCO_2 storage tank, and a resulting reliquefied fraction is returned to the intermediate LCO_2 storage tank. The present invention also relates to a corresponding method.

BACKGROUND ART

Captured and liquefied carbon dioxide can be transported in the liquid phase (LCO_2) from various locations and customers to CO_2 receiving terminals at which the CO_2 will be temporarily stored in intermediate buffer storage tanks onshore, before being pumped in a dense phase via a pipeline and injected into an offshore long term storage reservoir. The purpose of the buffer storage is to allow for continuous injection to the long-term storage reservoir despite intermittent LCO_2 cargo transfer from ship.

A general description of an outline of a CCS chain can be found in Conceptualization of CO_2 Terminal for Offshore CCS Using System Engineering Process by Hyonjeong et al. *Energies*, 2019, 12, 4350. Said CCS chain description includes the return of CO_2 carriers to consider the vaporised CO_2 (VCO_2) in returning carriers. According to Hyonjeong et al., the same volume of VCO_2 must be loaded into the carrier's cargo tank when unloading LCO_2 from the carrier to the CO_2 terminal. The carrier's cargo tank is displaced by the VCO_2 of the storage tanks at the terminal, while LCO_2 fills the storage tanks. There are two reasons for loading VCO_2 into the carrier's cargo tank. The first is to allow the pressure and temperature of the cargo tank to be controlled during the unloading process. Constant pressure and temperature facilitate the process. The second reason is to prevent the rapid decrease in temperature due to Joule–Thomson cooling.

Thus, for example, during LCO_2 cargo transfer between ship and onshore intermediate storage, the displaced vapour in the onshore intermediate storage tank could be returned to the CO_2 carrier ship via a vapour return connection for pressure maintenance in both sets of tanks, i.e. of the carrier ship and of the intermediate storage of the CO_2 receiving terminal, respectively.

However, depending on origin and purity of the LCO_2 being received at the terminal, the vapour in the onshore storage tank or tanks may contain impurities. In the event that restrictions are imposed on the vapour quality of vapour being returned to the ship that are not met by the vapour composition in the onshore storage, such impurities could pose a substantial impediment to the functioning of the CCS chain. In particular, LCO_2 receiving terminals served by multiple customers, with CO_2 originating from various sources, could face challenges from a technical and commercial point with undesired cross-contamination caused by impurities contained in the vapour space of the onshore storage tanks when returned to the ships.

It would be desirable to enable pressure maintenance in both sets of tanks, i.e. of the carrier ship and of the intermediate storage of the CO_2 receiving terminal, while reducing, and preferably avoiding, the risk of contaminating an LCO_2 carrier tank at a ship in connection with offloading LCO_2 from the ship to an LCO_2 receiving terminal. Moreover, this should preferably be achieved in an energy efficient manner.

It is an object of the present invention to provide a system and a method enabling the above.

SUMMARY OF THE INVENTION

The present invention is based on using a slip stream of LCO_2, which is being withdrawn from a main stream of LCO_2 being offloaded from a ship and imported to the terminal, for partially or completely reliquefying a stream of boil-off gas being withdrawn from an intermediate storage tank to which intermediate storage tank the LCO_2 main stream is being led, wherein the two streams are kept separate, and wherein a reliquefied fraction from the stream of boil-off gas is led back to the storage tank. The required cooling for reliquefaction of a fraction of the stream of boil-off gas is accomplished by subjecting the LCO_2 slip stream to a reduced pressure. The resulting cold partly vaporised LCO_2 slip stream, and the stream of boil-off gas are led to a heat exchanger for exchange of heat. After complete vaporisation of the LCO_2 slip stream, the resulting CO_2 vapour is led back to the ship in a vapour return conduit.

Accordingly, in one aspect the invention relates to a system **50** for offloading LCO_2 cargo from an LCO_2 carrier ship **30** to an intermediate LCO_2 storage tank **40** at an LCO_2 receiving terminal **100**, which system avoids cross-contamination of cargo from one LCO_2 carrier ship **30** to another, said system comprising: an intermediate LCO_2 storage tank **40**; a boil-off gas outlet **60** from the intermediate LCO_2 storage tank **40** configured to withdrawing boil-off gas from the intermediate LCO_2 storage tank **40**; an LCO_2 cargo import conduit **1, 10** connected to the intermediate LCO_2 storage tank **40** configured to receive an LCO_2 cargo import stream from the LCO_2 carrier ship **30**; a CO_2 vapour return conduit **4, 5, 6, 7, 8, 9** configured to be connected to the LCO_2 carrier ship **30** and to return from the system **50** CO_2 vapour to the LCO_2 carrier ship **30**; an LCO_2 outlet **70** from the intermediate LCO_2 storage tank **40** configured to discharging LCO_2 from the intermediate LCO_2 storage tank **40**; which system additionally comprises an LCO_2 slip stream conduit **2** connected to the LCO_2 cargo import conduit **1** configured to withdrawing a slip stream of LCO_2 from the LCO_2 cargo import conduit **1**; a pressure let-down valve **A** connected to the LCO_2 slip stream conduit **2** configured to receiving the slip stream of LCO_2 having a first temperature **T1**, and to exiting an at least partly vaporised stream of LCO_2 having a second lower temperature **T2**; a partly vaporised stream conduit **3** connected to the pressure let-down valve **A** configured to receiving the at least partly vaporised stream of LCO_2 having a second lower temperature **T2**; a boil-off gas conduit **11** connected to the boil-off gas outlet **60**; a first heat exchanger **B** connected to the partly vaporised stream conduit **3** and to the boil-off gas conduit **11**, respectively, said heat exchanger being configured to receiving the at least partly vaporised stream of LCO_2 having the second lower temperature **T2**, to receiving the boil-off gas withdrawn from the boil-off gas outlet **60**, to transferring heat from the boil-off gas to the at least partly vaporised stream of LCO_2 having the second lower temperature **T2**, to exiting a reliquefied fraction from the boil-off gas and to exiting an at least partly vaporised stream of LCO_2, respectively; a conduit **12, 15** connected to the intermediate LCO_2 storage tank **40** configured to receiving the exiting reliquefied fraction from the first heat exchanger **B**; wherein the CO_2 vapour return conduit **4, 5, 6, 7, 8, 9** is further configured to receive CO_2 vapour resulting from the at least partly vaporised stream of LCO_2 having the second lower temperature **T2**; and wherein a vapour return compressor **F** is arranged along the vapour return conduit **4, 5, 6, 7, 8, 9** configured to compressing the CO_2 vapour to be returned to the LCO_2 carrier ship **30.**

In a preferred embodiment of the system, the system additionally comprises means **C**, **D**, **E** configured to vaporising a remaining non-vaporised fraction of the at least partly vaporised stream of LCO_2 exiting the first heat exchanger **B**.

In yet a preferred embodiment of the system, the system comprises means **G**, **13**, **H**, **14,** configured to separate, compress, and direct a remaining gaseous fraction of the boil-off gas after partial reliquefaction thereof into a stream of compressed LCO_2 withdrawn from the intermediate LCO_2 storage tank **40** to be injected into a pipeline **110** connected to an underground long term storage reservoir **120**.

In another aspect, the invention relates to a method for offloading LCO_2 cargo from an LCO_2 carrier ship **30** to an intermediate LCO_2 storage tank **40** at an LCO_2 receiving terminal **100**, avoiding cross-contamination of cargo from one LCO_2 carrier ship **30** to another, said method comprising the following steps: **i.** receiving a main stream of LCO_2 from an LCO_2 carrier ship **30** and directing the main stream to an intermediate LCO_2 storage tank **40**; **ii.** withdrawing LCO_2 from an LCO_2 outlet **70** from the intermediate LCO_2 storage tank **40**; **iii.** withdrawing a stream of boil-off gas from a boil-off gas outlet **60** from the intermediate LCO_2 storage tank **40**; **iv.** returning CO_2 vapour from the terminal **100** back to the LCO_2 carrier ship **30**, which method additionally comprises the following steps: **v.** withdrawing from the main stream of LCO_2 a slip stream of LCO_2; **vi.** subjecting the withdrawn slip stream of LCO_2 having a first temperature **T1** to a reduced pressure, thereby partly vaporising the withdrawn LCO_2 slip stream having a first temperature **T1** so as to produce an at least partly vaporised LCO_2 slip stream having a second lower temperature **T2**; **vii.** subjecting the withdrawn stream of boil-off gas to heat exchange with the at least partly vaporised LCO_2 slip stream having the second lower temperature **T2**, thereby completely or partially liquefying the boil-off gas; **viii.**

returning the resulting liquefied fraction to the intermediate LCO_2 storage tank **40**; wherein, in step **iv.**, the CO_2 vapour from the terminal **100** being returned to the LCO_2 carrier ship **30** comprises a stream of CO_2 vapour obtained from the slip stream of LCO_2 and is subjected to compression before being returned to the ship.

In a preferred embodiment of the method, the method additionally comprises a step i**x.** wherein a remaining non-vaporised fraction of the at least partly vaporised LCO_2 slip stream after heat exchange in step **vii.** is vaporised, and, and wherein, in step **iv**., the CO_2 vapour from the terminal being compressed and returned to the LCO_2 carrier ship **30** comprises the resulting CO_2 vapour from step **ix**.

In yet a preferred embodiment of the method, the method additionally comprises the step **x.**, wherein, after heat exchange in step **vii.**, a remaining non-liquefied gaseous fraction from the boil-off gas stream is separated and directed into a stream of LCO_2 being with-drawn from the intermediate LCO_2 storage tank **40** and conveyed to an underground long term storage reservoir **120**.

The present invention provides a method and system providing vapour return for pres-sure support of LCO_2 carrier ship **30** tanks during liquid off-loading by generating vapours di-rectly from the off-loading cargo at the terminal **100**, eliminating the risk for potential off-spec vapour return from the onshore storage tank facility **40**.

Also, the invention provides an energy efficient measure to reliquefy displaced vapour in the onshore storage tanks **40**, by heat integration with the ship vapour return **4, 5, 6, 7, 8, 9**.

The present invention provides a method for force-vaporising a slip stream of the off-loaded LCO_2 cargo, providing vapour for pressure support to the ship tanks without ingress of any potential contaminants from the main onshore storage facility. The system also pro-vides cooling duty for reliquefaction of displaced vapour in the onshore storage tanks, reduc-ing the energy requirements for the BOG system.

The present invention achieves the advantage of providing CO_2 vapour return to an off-loading LCO_2 carrier ship **30**, independent of the content in the onshore storage tanks, i.e. avoiding exposure of potential contaminants contained in the vapour space from previous off-loaded cargos, such as from other LCO_2 carrier ships **30**.

Further embodiments and advantages of the invention will be apparent from the following detailed description and appended claims.

In the present disclosure, same reference numeral is used both to denote the conduit and the stream flowing therein. For example, reference numeral **2** is used to both denote the slip stream conduit, and also to denote the slip stream itself flowing in said conduit.

The term “long-term” as used herein denotes a storage intended to be permanent.

The present system and method may be combined with either one or both of the embodiments disclosed applicant’s co-pending applications filed on even date herewith.

BRIEF DESCRIPTION OF THE ATTACHED DRAWING

Figure 1 shows an embodiment of the inventive system **50** as indicated by the dashed line implemented into an LCO_2 receiving terminal **100**. The inventive system **50** in its most generic embodiment does not include **C**, **D**, **E**, which in a preferred embodiment can be arranged along the vapour return conduit **4, 5, 6, 7, 8, 9**, and does also not include **G** and **H**, which in a preferred embodiment can be provided for separating out a remaining gaseous fraction after partial liquefaction of the boil-off gas from the reliquefied conduit **12, 15**, and does also not include **I**, and **J**, which are units conventionally included in a conventional LCO_2 receiving terminal **100**, in which the inventive system **50** has not been implemented.

DETAILED DESCRIPTION OF THE INVENTION

The core of the invention is a process scheme that enables efficient heat integration between the cold closed-circuit vapour return stream to LCO_2 carrier ship **30** and the warmer displaced boil-off gas from the onshore storage tanks **40**. This is achieved by using a slip stream of the off-loaded LCO_2 cargo, which serves a dual purpose:

- as the CO_2 pressure is let down to e.g. 7 barg, the temperature will drop to approximately -45°C, providing refrigeration for the boil-off gas displaced during filling of onshore storage tanks **40**. This enables at least partial recovery of the boil-off gas, which is reliquefied and returned to the storage tank **40**;
- the cold low pressure LCO_2 is vaporised by indirect heat exchange in the first heat exchanger **B** which enables a closed-circuit vapour return system, eliminating the risk

for return of vapour potentially containing incompatible impurities from previous ships existing in the onshore storage tank facility.

In the above connection, a lower pressure will increase the cooling duty in the first heat exchanger **B**, but will also increase the compressor duty of vapour return compressor **F**.

Without CO_2 vapour return from the LCO_2 receiving terminal **100** to the LCO_2 carrier ship **30**, e.g. in order to avoid cross-contamination of the tanks of the LCO_2 carrier ship **30**, vapour for pressure maintenance on the ship could possibly alternatively be generated by force-vaporising liquid CO_2 cargo on the ship. Such solution is however considered inferior to the solution offered by the invention, since, i.a., with such solution, the displaced vapour in the intermediate LCO_2 storage tank or tanks **40** during filling will increase the sizing and energy requirements for the BOG system of the LCO_2 receiving terminal **100**.

In the embodiment of the invention illustrated in **FIG. 1**, LCO_2 is offloaded from a ship **30** at pressures from e.g. 15-18 barg (denoted as medium pressure (MP), with a typical saturation temperature between -30°C and -20°C).

A slip stream **2** of the off-loaded cargo **1** is fed to a pressure let-down control valve **A**, where the pressure is let down to e.g. 6-10 barg (denoted as low pressure (LP), with a typical saturation temperature between -50°C and -40°C).

The flow rate of the slip stream **2** will be determined by the off-loading rate, and typically around 5% of the total flow will be required.

On the downstream side **3** of the pressure let-down valve **A** a two-phase LP LCO_2 stream is fed to the first heat exchanger **B**. In the embodiment in **FIG. 1** the first heat exchanger **B** is depicted as a shell and tube heat exchanger but could alternatively be of another type, such as a plate or plate-fin heat exchanger. In the first heat exchanger **B**, the cold two-phase LP stream provides cooling of the vapour displaced **11** from the storage tank **40** during filling thereof. The displacement rate will depend on the filing rate **10**, the injection rate **16**, and the return of reliquefied boil-off gas **15**.

Ideally, in a case of operation wherein the two-phase LP LCO_2 stream has been fully vaporised after heat exchange **4** in the first heat exchanger **B**, the resulting CO_2 vapour is returned to the ship after compression of the CO_2 vapour stream **7** in a vapour return compressor **F**.

Following heat exchange in the first heat exchanger **B** in a case of operation wherein the partly vaporised LP LCO_2 stream **4** has not been fully vaporised, the stream is further vaporised in a second heat exchanger **C**, using the warm discharge stream **8** of vapour from the vapour return compressor **F**. In the inventive system, first and second heat exchangers **B** and **C**, respectively, could be referred to as cross heat exchangers.

In case the heat content of the boil-off stream **11** and of the compressor discharge stream **8** are not sufficient to completely vaporise the LP LCO_2, so that a partly vaporised LCO_2 stream **5** remains after the second heat exchanger **C**, a dedicated vaporiser **D** is provided. The vaporiser **D** could be heated electrically, by ambient sea water or other suitable heat sources available at the terminal **100**.

From the vaporiser **D** the LP CO_2 **6** is preferably fed to a knock-out drum **E** to ensure that any remaining liquid droplets are not found in the suction flow **7** to the vapour return compressor **F**.

The vapour return compressor **F** will increase the pressure to be compatible with the ship cargo tank pressure. The compressor discharge **8** is cooled by cross-heat exchange in heat exchanger **C**, providing heat for vaporisation of a remaining liquid phase in the LP LCO_2 stream **4** as described above.

Vapour **9** is returned to ship **30** at pressure and temperature compatible with the MP cargo at a rate that equals the volumetric flow of off-loaded liquid **1**.

As shown in the embodiment of the invention illustrated in **FIG. 1**, the offloaded LCO_2 is split into two process sections. As described above, the LP LCO_2 **2** is providing vapour for the displaced liquid in the ship cargo tanks **30** in a closed circuit **2, 3, 4, 5, 6, 7, 8, 9**. The major part of the imported LCO_2 **1** is transferred **10** at MP conditions to the intermediate storage tank(s) **40**.

The storage tank or tanks **40** are operated at MP condition, and liquid CO_2 is transferred **16** to injection pump or pumps **I**. In the embodiment of **FIG. 1**, the injection pump **I** is shown as a single pump but could also be configured in series with booster pumps. The pump(s) provide sufficient head for dense phase CO_2 to be exported to a pipeline **110** and subsequently injected into a reservoir **120** for permanent storage. Downstream of the injection pump **17**, an injection heater **J** may be arranged to avoid sub-zero temperatures entering the pipeline at the landfall **19**. The injection heater **J** could for example be heated electrically, by ambient sea water or other suitable heat sources available at the terminal.

During cargo import, the export flow rate **16** is likely to be lower than cargo transfer rate **10**, hence, as the level in the intermediate storage tank **40** increases vapour will be displaced. To control pressure, the displaced vapour **11** will need to be processed, to avoid CO_2 emission to atmosphere by vent.

The displaced vapour **11** at MP conditions will be reliquefied against the colder LP LCO_2 stream **3** in a heat exchanger **B**. Ideally, in a case of operation wherein the BOG and/or displaced vapour **11** can be completely reliquefied, the reliquefied BOG or reliquefied displaced vapour can be returned to intermediate storage tank **40** via conduit **12, 15**. In a case of operation wherein a gaseous fraction remains **12** after cooling in the vapour return heat exchanger **B**, the partly reliquefied vapours **12** are fed to a two-phase separator **G**, where reliquefied BOG/reliquefied displaced vapour is returned **15** to the intermediate storage tank **40**. The gas phase **13**, enriched with non-condensable impurities, is fed to a boil-off gas compressor **H** and the effluent from the compressor is injected into high-pressure LCO_2 in the export conduit **18**, where it will be dissolved, complying with single phase flow assurance requirements.

LIST OF REFERENCE SIGNS USED

1, 10	LCO_2 cargo import conduit
2	LCO_2 slip stream conduit
3	partly vaporised LCO_2 stream conduit
4, 5, 6, 7, 8, 9	CO_2 vapour return conduit
11	boil-off gas conduit
12, 13, 14	remaining gaseous fraction conduit (from boil-off gas)
12, 15	reliquefied fraction conduit
16	conduit connecting bottom outlet 70 with injection pump I
17	conduit connecting outlet from injection pump with injection heater J
30	LCO_2 carrier ship
40	intermediate LCO_2 storage tank
50	system for offloading LCO_2 cargo (from an LCO_2 carrier ship)
60	boil-off gas outlet (from intermediate LCO_2 storage tank)
70	LCO_2 outlet (from intermediate LCO_2 storage tank)
100	LCO_2 receiving terminal
110	pipeline
120	underground long term storage reservoir
T1	first temperature (of slip stream)
T2	second lower temperature (of partly vaporised LCO_2 stream)
A	pressure let-down valve
B	first heat exchanger
C	second heat exchanger
D	vaporiser
E	knock-out drum
F	vapour return compressor
G	two-phase separator
H	boil-off gas compressor
I	injection pump
J	injection heater

CLAIMS

1. A system (50) for offloading LCO_2 cargo from an LCO_2 carrier ship (30) to an intermediate LCO_2 storage tank (40) at an LCO_2 receiving terminal (100), which system avoids cross-contamination of cargo from one LCO_2 carrier ship (30) to another, said system comprising:

- an intermediate LCO_2 storage tank (40);

- a boil-off gas outlet (60) from the intermediate LCO_2 storage tank (40) configured to withdrawing boil-off gas from the intermediate LCO_2 storage tank (40);

- an LCO_2 cargo import conduit (1, 10) connected to the intermediate LCO_2 storage tank (40) configured to receive an LCO_2 cargo import stream from the LCO_2 carrier ship (30);

- a CO_2 vapour return conduit (4, 5, 6, 7, 8, 9) configured to be connected to the LCO_2 carrier ship (30) and to return from the system (50) CO_2 vapour to the LCO_2 carrier ship (30);

- an LCO_2 outlet (70) from the intermediate LCO_2 storage tank (40) configured to discharging LCO_2 from the intermediate LCO_2 storage tank (40);

characterized in additionally comprising,

- an LCO_2 slip stream conduit (2) connected to the LCO_2 cargo import conduit (1) configured to withdrawing a slip stream of LCO_2 from the LCO_2 cargo import conduit (1);

- a pressure let-down valve (A) connected to the LCO_2 slip stream conduit (2) configured to receiving the slip stream of LCO_2 having a first temperature (T1), and to exiting an at least partly vaporised stream of LCO_2 having a second lower temperature (T2);

- a partly vaporised stream conduit (3) connected to the pressure let-down valve (A) configured to receiving the at least partly vaporised stream of LCO_2 having a second lower temperature (T2);

- a boil-off gas conduit (11) connected to the boil off gas outlet (60);

- a first heat exchanger (B) connected to the partly vaporised stream conduit (3) and to the boil-off gas conduit (11), respectively, said heat exchanger being configured to receiving the at least partly vaporised stream of LCO_2 having the second lower temperature (T2), to receiving the boil-off gas withdrawn from the boil-off gas outlet (60), to transferring heat from the boil-off gas to the at least partly vaporised stream of LCO_2 having the second lower temperature (T2), to exiting a reliquefied fraction from boil-off gas and to exiting an at least partly vaporised stream of LCO_2, respectively;

- a reliquefied fraction conduit (12, 15) connected to the intermediate LCO_2 storage tank (40) configured to receiving the exiting reliquefied fraction from the first heat exchanger (B);

- wherein the CO_2 vapour return conduit (4, 5, 6, 7, 8, 9) is further configured to receiving CO_2 vapour resulting from the at least partly vaporised stream of LCO_2 having the second lower temperature (T2); and

- a vapour return compressor (F) arranged along the vapour return conduit (4, 5, 6, 7, 8, 9) configured to compressing the CO_2 vapour to be returned to the LCO_2 carrier ship (30).

2 The system (50) of claim 1, additionally comprising

- means (C, D, E) arranged along the CO_2 vapour return conduit (4, 5, 6, 7, 8, 9) configured to vaporising a remaining non-vaporised fraction of the at least partly vaporised stream of LCO_2 exiting the first heat exchanger (B).

3. The system (50) of claim 1 or 2, additionally comprising

- an injection pump (I) connected via a conduit (16) to the LCO_2 outlet (70) from the intermediate LCO_2 storage tank (40) configured to receiving LCO_2 withdrawn from the intermediate LCO_2 storage tank (40), and to ejecting a stream of compressed LCO_2 to be injected into a pipeline (110) connected to an underground long term storage reservoir (120); and

- a remaining gaseous fraction conduit (12, 13, 14) and means (G,H) arranged along said remaining gaseous fraction conduit (12, 13, 14) configured to receiving, separating from the reliquefied fraction conduit (12, 15), and compressing, a remaining gaseous fraction exiting the first heat exchanger (B) resulting from the boil-off gas, and to injecting the resulting compressed gaseous fraction of the boil-off gas into a stream of compressed LCO_2 to be injected into a pipeline (110) connected to an underground long term storage reservoir (120).

4. A method for offloading LCO_2 cargo from an LCO_2 carrier ship (30) to an intermediate LCO_2 storage tank (40) at an LCO_2 receiving terminal (100), avoiding cross-contamination of cargo from one LCO_2 carrier ship (30) to another, said method comprising the following steps:

i.) receiving a main stream of LCO_2 from an LCO_2 carrier ship (30) and directing the main stream to an intermediate LCO_2 storage tank (40);

ii.) withdrawing LCO_2 from an LCO_2 outlet (70) from the intermediate LCO_2 storage tank (40);

iii.) withdrawing a stream of boil-off gas from a boil-off gas outlet (60) from the intermediate LCO_2 storage tank (40);

iv.) returning CO_2 vapour from the terminal (100) back to the LCO_2 carrier ship (30),

characterized in additionally comprising the following steps:

v.) withdrawing from the main stream of LCO_2 a slip stream of LCO_2;

vi.) subjecting the withdrawn slip stream of LCO_2 having a first temperature (T1) to a reduced pressure, thereby partly vaporising the withdrawn LCO_2 slip stream having a first temperature (T1) so as to produce an at least partly vaporised LCO_2 slip stream having a second lower temperature (T2);

vii.) subjecting the withdrawn stream of boil-off gas to heat exchange with the at least partly vaporised LCO_2 slip stream having the second lower temperature (T2), thereby partly or completely liquefying the stream of boil-off gas into a liquefied fraction;

viii.) returning the resulting liquefied fraction to the intermediate LCO_2 storage tank (40);

wherein, in step (iv.), the CO_2 vapour from the terminal (100) being returned to the LCO_2 carrier ship (30) comprises a stream of CO_2 vapour obtained from the slip stream of LCO_2 and is subjected to compression before being returned to the ship.

5. The method for offloading LCO_2 cargo from an LCO_2 carrier ship (30) to an intermediate LCO_2 storage tank (40) at an LCO_2 receiving terminal (100) of claim 4, additionally comprising the following steps:

ix.) vaporising a remaining non-vaporised fraction of the at least partly vaporised LCO_2 slip stream after heat exchange in step (vii);

wherein, in step (iv.), the CO_2 vapour from the terminal being compressed and returned to the LCO_2 carrier ship (30) comprises the resulting CO_2 vapour from step (ix.).

6. The method of claim 4 or 5, additionally comprising the step of:

x.) after heat exchange in step (vii.) separating and directing a remaining non-liquefied gaseous fraction from the boil-off gas stream into a stream of LCO_2 being withdrawn from the intermediate LCO_2 storage tank (40) and conveyed to an underground long term storage reservoir (120).

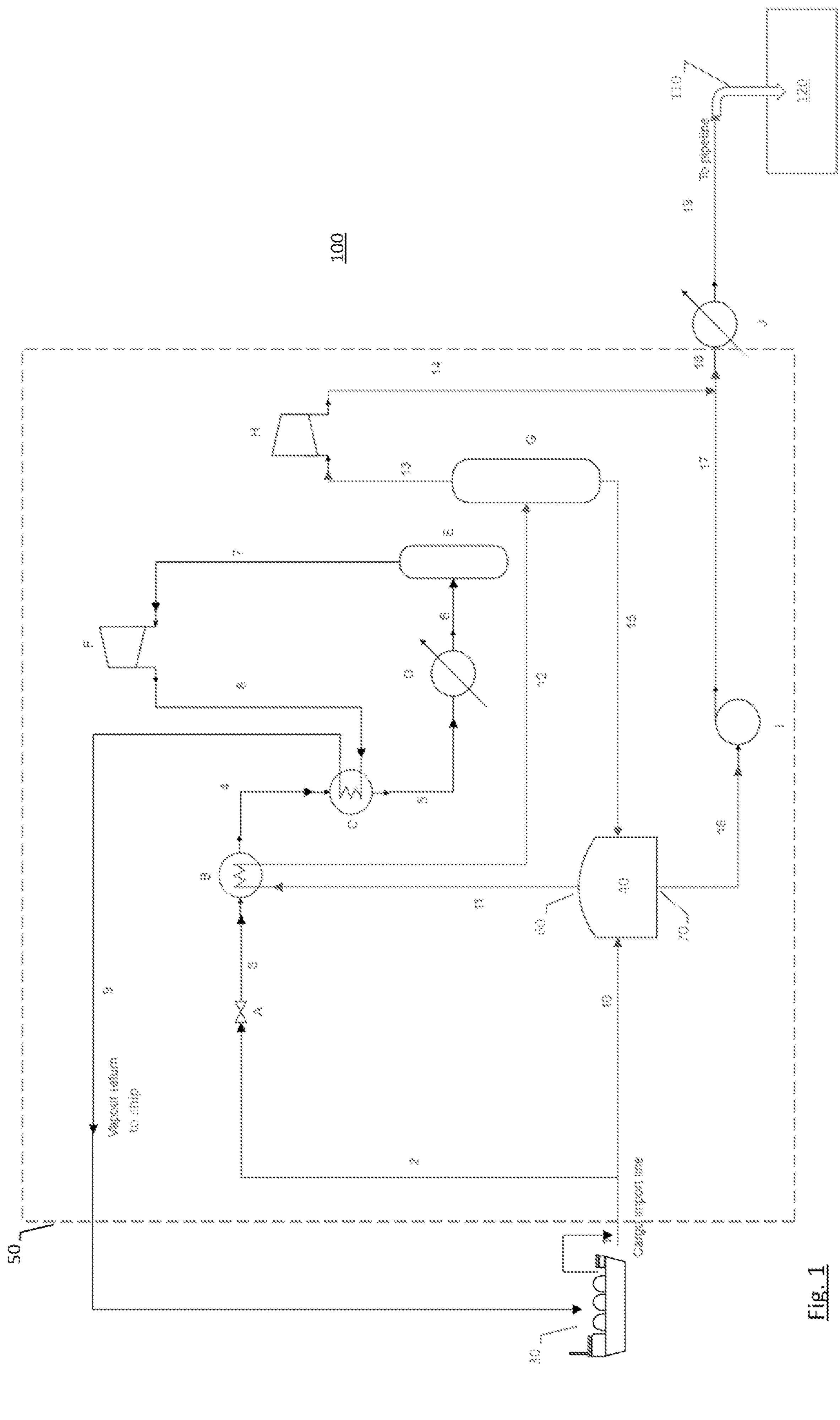

100
50
Vapour return to ship
Cargo import line
To pipeline
120
110

Fig. 1