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

SYSTEM UND VERFAHREN ZUM ENTLADEN VON LCO2 VON EINEM SCHIFF ZU EINEM ZWISCHENSPEICHER AN EINEM LCO2-EMPFANGSENDGERÄT

SYSTÈME ET PROCÉDÉ DE DÉCHARGEMENT DE LCO2 D'UN NAVIRE VERS UNE MÉMOIRE INTERMÉDIAIRE AU NIVEAU D'UN TERMINAL DE RÉCEPTION LCO2

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- **NOH HYONJEONG ET AL: "Conceptualization of CO2 Terminal for Offshore CCS Using System Engineering Process", ENERGIES, vol. 12, no. 22, 15 November 2019 (2019-11-15), pages 4350, XP093055447, DOI: 10.3390/en12224350**

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Description

FIELD OF THE INVENTION

[0001] The present invention generally relates to Carbon Capture and Storage (CCS) technology, and more particularly to a system for offloading liquid CO₂ (LCO₂) from an LCO₂ carrier ship to an intermediate LCO₂ storage tank at an LCO₂ receiving terminal connected to a long term LCO₂ storage facility, 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 The invention uses a slip stream of LCO₂ withdrawn from a main stream of LCO₂ being offloaded to the terminal which is vaporised and returned to the LCO₂ carrier ship, and the vaporisation is used to providing cooling for complete or partial reliquefaction of a boil-off gas stream withdrawn from the intermediate LCO₂ storage tank, and a resulting reliquefied fraction is returned to the intermediate LCO₂ storage tank. The present invention also relates to a corresponding method.

BACKGROUND ART

[0002] Captured and liquefied carbon dioxide can be transported in the liquid phase (LCO₂) from various locations and customers to CO₂ receiving terminals at which the CO₂ 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 LCO₂ cargo transfer from ship.

[0003] A general description of an outline of a CCS chain can be found in Conceptualization of CO₂ Terminal for Offshore CCS Using System Engineering Process by Hyonjeong et al. Energies, 2019, 12, 4350. Said CCS chain description includes the return of CO₂ carriers to consider the vaporised CO₂ (VCO₂) in returning carriers. According to Hyonjeong et al., the same volume of VCO₂ must be loaded into the carrier's cargo tank when unloading LCO₂ from the carrier to the CO₂ terminal. The carrier's cargo tank is displaced by the VCO₂ of the storage tanks at the terminal, while LCO₂ fills the storage tanks. There are two reasons for loading VCO₂ 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.

[0004] Thus, for example, during LCO₂ cargo transfer between ship and onshore intermediate storage, the displaced vapour in the onshore intermediate storage tank could be returned to the CO₂ 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 CO₂ receiving terminal, respectively.

[0005] However, depending on origin and purity of the LCO₂ 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, LCO₂ receiving terminals served by multiple customers, with CO₂ 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.

[0006] 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 CO₂ receiving terminal, while reducing, and preferably avoiding, the risk of contaminating an LCO₂ carrier tank at a ship in connection with offloading LCO₂ from the ship to an LCO₂ receiving terminal. Moreover, this should preferably be achieved in an energy efficient manner.

[0007] It is an object of the present invention to provide a system and a method enabling the above.

SUMMARY OF THE INVENTION

[0008] The present invention is based on using a slip stream of LCO₂, which is being withdrawn from a main stream LCO₂ 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 LCO₂ 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 LCO₂ slip stream to a reduced pressure. The resulting cold partly vaporised LCO₂ slip stream, and the stream of boil-off gas are led to a heat exchanger for exchange of heat. After complete vaporisation of the LCO₂ slip stream, the resulting CO₂ vapour is led back to the ship in a vapour return conduit.

[0009] Accordingly, in one aspect the invention relates to a system **50** for offloading LCO₂ cargo from an LCO₂ carrier ship **30** to an intermediate LCO₂ storage tank **40** at an LCO₂ receiving terminal **100**, which system avoids cross-contamination of cargo from one LCO₂ carrier ship **30** to another, said system comprising: an intermediate LCO₂ storage tank **40**; a boil-off gas outlet **60** from the intermediate LCO₂ storage tank **40** configured to withdrawing boil-off gas from the intermediate LCO₂ storage tank **40**; an LCO₂ cargo import conduit **1**, **10** connected to the intermediate LCO₂ storage tank **40** configured to receive an LCO₂ cargo import stream from the LCO₂

carrier ship **30**; a CO₂ vapour return conduit **4, 5, 6, 7, 8, 9** configured to be connected to the LCO₂ carrier ship **30** and to return from the system **50** CO₂ vapour to the LCO₂ carrier ship **30**; an LCO₂ outlet **70** from the intermediate LCO₂ storage tank **40** configured to discharging LCO₂ from the intermediate LCO₂ storage tank **40**; which system additionally comprises an LCO₂ slip stream conduit **2** connected to the LCO₂ cargo import conduit **1** configured to withdrawing a slip stream of LCO₂ from the LCO₂ cargo import conduit **1**; a pressure let-down valve **A** connected to the LCO₂ slip stream conduit **2** configured to receiving the slip stream of LCO₂ having a first temperature **T1**, and to exiting an at least partly vaporised stream of LCO₂ 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 LCO₂ 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 LCO₂ 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 LCO₂ 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 LCO₂, respectively; a conduit **12, 15** connected to the intermediate LCO₂ storage tank **40** configured to receiving the exiting reliquefied fraction from the first heat exchanger **B**; wherein the CO₂ vapour return conduit **4, 5, 6, 7, 8, 9** is further configured to receive CO₂ vapour resulting from the at least partly vaporised stream of LCO₂ 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 CO₂ vapour to be returned to the LCO₂ carrier ship **30**.

[0010] 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 LCO₂ exiting the first heat exchanger **B**.

[0011] 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 LCO₂ withdrawn from the intermediate LCO₂ storage tank **40** to be injected into a pipeline **110** connected to an underground long term storage facility **120**.

[0012] In another aspect, the invention relates to a method for offloading LCO₂ cargo from an LCO₂ carrier ship **30** to an intermediate LCO₂ storage tank **40** at an LCO₂ receiving terminal **100**, avoiding cross-contamination of cargo from one LCO₂ carrier ship **30** to another, said method comprising the following steps: i. receiving a

main stream of LCO₂ from an LCO₂ carrier ship **30** and directing the main stream to an intermediate LCO₂ storage tank **40**; ii. withdrawing LCO₂ from an LCO₂ outlet **70** from the intermediate LCO₂ storage tank **40**; iii. withdrawing a stream of boil-off gas from a boil-off gas outlet **60** from the intermediate LCO₂ storage tank **40**; iv. returning CO₂ vapour from the terminal **100** back to the LCO₂ carrier ship **30**, which method additionally comprises the following steps: v. withdrawing from the main stream of LCO₂ a slip stream of LCO₂; vi. subjecting the withdrawn slip stream of LCO₂ having a first temperature **T1** to a reduced pressure, thereby partly vaporising the withdrawn LCO₂ slip stream having a first temperature **T1** so as to produce an at least partly vaporised LCO₂ 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 LCO₂ 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 LCO₂ storage tank **40**; wherein, in step iv., the CO₂ vapour from the terminal **100** being returned to the LCO₂ carrier ship **30** comprises a stream of CO₂ vapour obtained from the slip stream of LCO₂ and is subjected to compression before being returned to the ship.

[0013] In a preferred embodiment of the method, the method additionally comprises a step ix. wherein a remaining non-vaporised fraction of the at least partly vaporised LCO₂ slip stream after heat exchange in step vii. is vaporised, and, and wherein, in step iv., the CO₂ vapour from the terminal being compressed and returned to the LCO₂ carrier ship **30** comprises the resulting CO₂ vapour from step ix.

[0014] 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 LCO₂ being withdrawn from the intermediate LCO₂ storage tank **40** and conveyed to an underground long term storage facility **120**.

[0015] The present invention provides a method and system providing vapour return for pressure support of LCO₂ carrier ship **30** tanks during liquid off-loading by generating vapours directly 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**.

[0016] 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**.

[0017] The present invention provides a method for a force-vaporising a slip stream of the off-loaded LCO₂ 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 provides cooling duty for reliquefaction of displaced vapour in the onshore storage tanks, reducing the energy requirements for the BOG system.

[0018] The present invention achieves the advantage of providing CO₂ vapour return to an off-loading LCO₂ 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 LCO₂ carrier ships **30**.

[0019] Further embodiments and advantages of the invention will be apparent from the following detailed description and appended claims.

[0020] 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.

[0021] The term "long-term" as used herein denotes a storage intended to be permanent.

[0022] 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

[0023] Figure 1 shows an embodiment of the inventive system **50** as indicated by the dashed line implemented into an LCO₂ 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 LCO₂ receiving terminal **100**, in which the inventive system **50** has not been implemented.

DETAILED DESCRIPTION OF THE INVENTION

[0024] The core of the invention is a process scheme that enables efficient heat integration between the cold closed-circuit vapour return stream to LCO₂ 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 LCO₂ cargo, which serves a dual purpose:

- as the CO₂ 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 LCO₂ 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.

[0025] 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**.

[0026] Without CO₂ vapour return from the LCO₂ receiving terminal **100** to the LCO₂ carrier ship **30**, e.g. in order to avoid cross-contamination of the tanks of the LCO₂ carrier ship **30**, vapour for pressure maintenance on the ship could possibly alternatively be generated by force-vaporising liquid CO₂ 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 LCO₂ storage tank or tanks **40** during filling will increase the sizing and energy requirements for the BOG system of the LCO₂ receiving terminal **100**.

[0027] In the embodiment of the invention illustrated in **FIG. 1**, LCO₂ 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).

[0028] 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).

[0029] 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.

[0030] On the downstream side **3** of the pressure let-down valve **A** a two-phase LP LCO₂ 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 filling rate **10**, the injection rate **16**, and the return of reliquefied boil-off gas **15**.

[0031] Ideally, in a case of operation wherein the two-phase LP LCO₂ stream has been fully vaporised after heat exchange **4** in the first heat exchanger **B**, the resulting CO₂ vapour is returned to the ship after compression of the CO₂ vapour stream **7** in a vapour return compressor **F**.

[0032] Following heat exchange in the first heat exchanger **B** in a case of operation wherein the partly vaporised LP LCO₂ 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.

[0033] 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 LCO₂, so that a partly vaporised LCO₂ 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**.

[0034] From the vaporiser **D** the LP CO₂ **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**.

[0035] 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 LCO₂ stream **4** as described above.

[0036] 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**.

[0037] As shown in the embodiment of the invention illustrated in **FIG. 1**, the offloaded LCO₂ is split into two process sections. As described above, the LP LCO₂ **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 LCO₂ **1** is transferred **10** at MP conditions to the intermediate storage tank(s) **40**.

[0038] The storage tank or tanks **40** are operated at MP condition, and liquid CO₂ 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 CO₂ 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.

[0039] 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 CO₂ emission to atmosphere by vent.

[0040] The displaced vapour **11** at MP conditions will be reliquefied against the colder LP LCO₂ 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 LCO₂ in the export conduit **18**, where it will be dissolved, complying with single phase flow assurance requirements.

10 LIST OF REFERENCE SIGNS USED

[0041]

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, 11	9 CO ₂ vapour return conduit	
12, 13, 14	boil-off gas conduit	
20	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	
25	30	LCO ₂ carrier ship
40	intermediate LCO ₂ storage tank	
50	system for offloading LCO ₂ cargo (from an LCO ₂ carrier ship)	
30	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	
35	110	pipeline
120	underground long term storage facility	
T1	first temperature (of slip stream)	
T2	second lower temperature (of partly vaporised LCO ₂ stream)	
40	A	pressure let-down valve
B	first heat exchanger	
C	second heat exchanger	
D	vaporiser	
E	knock-out drum	
45	F	vapour return compressor
G	two-phase separator	
H	boil-off gas compressor	
I	injection pump	
J	injection heater	

50 Claims

1. A system (50) for offloading LCO₂ cargo from an LCO₂ carrier ship (30) to an intermediate LCO₂ storage tank (40) at an LCO₂ receiving terminal (100), which system avoids cross-contamination of cargo from one LCO₂ carrier ship (30) to another, said system comprising:

- an intermediate LCO₂ storage tank (40);
 - a boil-off gas outlet (60) from the intermediate LCO₂ storage tank (40) configured to withdrawing boil-off gas from the intermediate LCO₂ storage tank (40);
 - an LCO₂ cargo import conduit (1, 10) connected to the intermediate LCO₂ storage tank (40) configured to receive an LCO₂ cargo import stream from the LCO₂ carrier ship (30);
 - a CO₂ vapour return conduit (4, 5, 6, 7, 8, 9) configured to be connected to the LCO₂ carrier ship (30) and to return from the system (50) CO₂ vapour to the LCO₂ carrier ship (30);
 - an LCO₂ outlet (70) from the intermediate LCO₂ storage tank (40) configured to discharging LCO₂ from the intermediate LCO₂ storage tank (40);

characterized in additionally comprising,
 - an LCO₂ slip stream conduit (2) connected to the LCO₂ cargo import conduit (1) configured to withdrawing a slip stream of LCO₂ from the LCO₂ cargo import conduit (1);
 - a pressure let-down valve (A) connected to the LCO₂ slip stream conduit (2) configured to receiving the slip stream of LCO₂ having a first temperature (T1), and to exiting an at least partly vaporised stream of LCO₂ 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 LCO₂ 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 LCO₂ 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 LCO₂ 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 LCO₂, respectively;
 - a reliquefied fraction conduit (12, 15) connected to the intermediate LCO₂ storage tank (40) configured to receiving the exiting reliquefied fraction from the first heat exchanger (B);
 - wherein the CO₂ vapour return conduit (4, 5, 6, 7, 8, 9) is further configured to receiving CO₂ vapour resulting from the at least partly vaporised stream of LCO₂ 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 CO₂ vapour to be returned to the LCO₂ carrier ship (30).

- 5 2. The system (50) of claim 1, additionally comprising
- means (C, D, E) arranged along the CO₂ 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 LCO₂ exiting the first heat exchanger (B).
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3. The system (50) of claim 1 or 2, additionally comprising
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- an injection pump (I) connected via a conduit (16) to the LCO₂ outlet (70) from the intermediate LCO₂ storage tank (40) configured to receiving LCO₂ withdrawn from the intermediate LCO₂ storage tank (40), and to ejecting a stream of compressed LCO₂ to be injected into a pipeline (110) connected to an underground long term storage facility (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 LCO₂ to be injected into a pipeline (110) connected to an underground long term storage facility (120).
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4. A method for offloading LCO₂ cargo from an LCO₂ carrier ship (30) to an intermediate LCO₂ storage tank (40) at an LCO₂ receiving terminal (100), avoiding cross-contamination of cargo from one LCO₂ carrier ship (30) to another, said method comprising the following steps:
- i.) receiving a main stream of LCO₂ from an LCO₂ carrier ship (30) and directing the main stream to an intermediate LCO₂ storage tank (40);
 ii.) withdrawing LCO₂ from an LCO₂ outlet (70) from the intermediate LCO₂ storage tank (40);
 iii.) withdrawing a stream of boil-off gas from a boil-off gas outlet (60) from the intermediate LCO₂ storage tank (40);
 iv.) returning CO₂ vapour from the terminal (100) back to the LCO₂ carrier ship (30),

characterized in additionally comprising the following steps:

v.) withdrawing from the main stream of LCO₂ a slip stream of LCO₂;

vi.) subjecting the withdrawn slip stream of LCO₂ having a first temperature (T1) to a reduced pressure, thereby partly vaporising the withdrawn LCO₂ slip stream having a first temperature (T1) so as to produce an at least partly vaporised LCO₂ 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 LCO₂ 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 LCO₂ storage tank (40); wherein, in step (iv.), the CO₂ vapour from the terminal (100) being returned to the LCO₂ carrier ship (30) comprises a stream of CO₂ vapour obtained from the slip stream of LCO₂ and is subjected to compression before being returned to the ship.

5. The method for offloading LCO₂ cargo from an LCO₂ carrier ship (30) to an intermediate LCO₂ storage tank (40) at an LCO₂ receiving terminal (100) of claim 4, additionally comprising the following steps:

ix.) vaporising a remaining non-vaporised fraction of the at least partly vaporised LCO₂ slip stream after heat exchange in step (vii); wherein, in step (iv.), the CO₂ vapour from the terminal being compressed and returned to the LCO₂ carrier ship (30) comprises the resulting CO₂ 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 LCO₂ being withdrawn from the intermediate LCO₂ storage tank (40) and conveyed to an underground long term storage facility (120).

Patentansprüche

1. System (50) zum Entladen von LCO₂-Fracht von einem LCO₂-Tanker (30) in einen LCO₂-Zwischenspeichertank (40) an einem LCO₂-Empfangsterminal (100), wobei das System eine Kreuzkontamination der Fracht von einem LCO₂-Tanker (30) auf einen anderen vermeidet, wobei das System aufweist:

- einen LCO₂-Zwischenspeichertank (40);

- einen Abdampfgas-Auslass (60) aus dem LCO₂-Zwischenspeichertank (40), der konfiguriert ist, Abdampfgas aus dem LCO₂-Zwischenspeichertank (40) zu entnehmen;

- eine LCO₂-Frachtimportleitung (1, 10), die mit dem LCO₂-Zwischenspeichertank (40) verbunden ist und konfiguriert ist, einen LCO₂-Frachtimportstrom vom LCO₂-Tanker (30) aufzunehmen;

- eine CO₂-Dampfdruckföhrleitung (4, 5, 6, 7, 8, 9), die konfiguriert ist, mit dem LCO₂-Tanker (30) verbunden zu werden und CO₂-Dampf aus dem System (50) zum LCO₂-Tanker (30) zurückzuföhren;

- einen LCO₂-Auslass (70) aus dem LCO₂-Zwischenspeichertank (40), der konfiguriert ist, LCO₂ aus dem LCO₂-Zwischenspeichertank (40) abzugeben;

dadurch gekennzeichnet, dass es zusätzlich aufweist:

- eine LCO₂-Nachstromleitung (2), die mit der LCO₂-Frachtimportleitung (1) verbunden ist und konfiguriert ist, einen LCO₂-Nachstrom aus der LCO₂-Frachtimportleitung (1) zu entnehmen;

- ein Druckabbauventil (A), das mit der LCO₂-Nachstromleitung (2) verbunden und konfiguriert ist, den LCO₂-Nachstrom mit einer ersten Temperatur (T1) aufzunehmen und einen zumindest teilweise verdampften LCO₂-Strom mit einer zweiten, niedrigeren Temperatur (T2) austreten zu lassen;

- eine Leitung (3) für einen teilweise verdampften Strom, die mit dem Druckabbauventil (A) verbunden und konfiguriert ist, den mindestens teilweise verdampften LCO₂-Strom mit einer zweiten niedrigeren Temperatur (T2) aufzunehmen;

- eine Abdampfgas-Leitung (11), die mit dem Abdampfgas-Auslass (60) verbunden ist;

- einen ersten Wärmetauscher (B), der mit der Leitung (3) für den teilweise verdampften Strom bzw. mit der Abdampfgas-Leitung (11) verbunden ist, wobei der Wärmetauscher konfiguriert ist, den zumindest teilweise verdampften LCO₂-Strom mit der zweiten niedrigeren Temperatur (T2) aufzunehmen, das aus dem Abdampfgas-Auslass (60) entnommene Abdampfgas aufzunehmen, Wärme von dem Abdampfgas auf den zumindest teilweise verdampften LCO₂-Strom mit der zweiten niedrigeren Temperatur (T2) zu übertragen, einen wieder verflüssigten Anteil aus dem Abdampfgas austreten zu lassen bzw. einen zumindest teilweise verdampften LCO₂-Strom austreten zu lassen;

- eine Leitung (12, 15) für den wieder verflüssigten Anteil, die mit dem LCO₂-Zwischenspei-

- chertank (40) verbunden und konfiguriert ist, den aus dem ersten Wärmetauscher (B) austretenden wieder verflüssigten Anteil aufzunehmen;
- wobei die CO₂-Dampfdruckföhrleitung (4, 5, 6, 7, 8, 9) ferner konfiguriert ist, CO₂-Dampf aufzunehmen, der aus dem zumindest teilweise verdampften LCO₂-Strom mit der zweiten niedrigeren Temperatur (T2) resultiert; und
 - einen Dampfdruckföhrverdichter (F), der entlang der Dampfdruckföhrleitung (4, 5, 6, 7, 8, 9) angeordnet ist und konfiguriert ist, den CO₂-Dampf zu verdichten, der zum LCO₂-Tanker (30) zuröckgeföhrt werden soll.
2. System (50) nach Anspruch 1, das zusätzlich aufweist:
- eine Einrichtung (C, D, E), die entlang der CO₂-Dampfdruckföhrleitung (4, 5, 6, 7, 8, 9) angeordnet und konfiguriert ist, einen verbleibenden nicht verdampften Anteil des zumindest teilweise verdampften LCO₂-Stroms, der aus dem ersten Wärmetauscher (B) austritt, zu verdampfen.
3. System (50) nach Anspruch 1 oder 2, das zusätzlich aufweist:
- eine Einspritzpumpe (I), die über eine Leitung (16) mit dem LCO₂-Auslass (70) des LCO₂-Zwischenspeichertanks (40) verbunden ist, die konfiguriert ist, LCO₂ aufzunehmen, das aus dem LCO₂-Zwischenspeichertank (40) entnommen wird, und einen Strom von verdichtetem LCO₂ auszustoßen, der in eine Pipeline (110) eingespritzt werden soll, die mit einer unterirdischen Langzeitspeichereinrichtung (120) verbunden ist; und
 - eine Leitung (12, 13, 14) für den verbleibenden gasförmigen Anteil und eine Einrichtung (G, H), die entlang der Leitung (12, 13, 14) für den verbleibenden gasförmigen Anteil angeordnet und konfiguriert sind, einen verbleibenden gasförmigen Anteil, der aus dem ersten Wärmetauscher (B) austritt und aus dem verdampften Gas resultiert, aufzunehmen, von der Leitung (12, 15) für den wieder verflüssigten Anteil zu trennen und zu verdichten, und den resultierenden verdichteten gasförmigen Anteil des Abdampfes in einen Strom von verdichtetem LCO₂ einzuspritzen, der in eine Pipeline (110) eingespritzt werden soll, die mit einer unterirdischen Langzeitspeichereinrichtung (120) verbunden ist.
4. Verfahren zum Entladen einer LCO₂-Fracht von einem LCO₂-Tanker (30) in einen LCO₂-Zwischenspeichertank (40) an einem LCO₂-Empfangstermi-

nal (100), wobei eine Kreuzkontamination der Fracht von einem LCO₂-Tanker (30) auf einen anderen vermieden wird, wobei das Verfahren die folgenden Schritte aufweist:

- i.) Empfangen eines Hauptstroms von LCO₂ von einem LCO₂-Tanker (30) und Leiten des Hauptstroms zu einem LCO₂-Zwischenspeichertank (40);
- ii.) Entnehmen von LCO₂ aus einem LCO₂-Auslass (70) aus dem LCO₂-Zwischenspeichertank (40);
- iii.) Entnehmen eines Abdampfes-Stroms aus einem Abdampfes-Auslass (60) aus dem LCO₂-Zwischenspeichertank (40);
- iv.) Röckföhren von CO₂-Dampf vom Terminal (100) zuröck zum LCO₂-Tanker (30),

dadurch gekennzeichnet, dass es zusätzlich die folgenden Schritte aufweist:

- v.) Entnehmen aus dem Hauptstrom von LCO₂ eines LCO₂-Nachstroms;
- vi.) Aussetzen des entnommenen LCO₂-Nachstroms mit einer ersten Temperatur (T1) einem reduzierten Druck, wodurch der entnommene LCO₂-Nachstrom mit einer ersten Temperatur (T1) teilweise verdampft wird, um einen zumindest teilweise verdampften LCO₂-Nachstrom mit einer zweiten niedrigeren Temperatur (T2) zu erzeugen;
- vii.) Unterziehen des entnommenen Abdampfes-Stroms einem Wärmeaustausch mit dem zumindest teilweise verdampften LCO₂-Nachstrom mit der zweiten niedrigeren Temperatur (T2), wodurch der Abdampfes-Strom teilweise oder vollständig zu einem verflüssigten Anteil verflüssigt wird;
- viii.) Röckföhren des resultierenden verflüssigten Anteils in den LCO₂-Zwischenspeichertank (40);

wobei in Schritt (iv.) der CO₂-Dampf von dem Terminal (100), der zu dem LCO₂-Tanker (30) zuröckgeföhrt wird, einen Strom von CO₂-Dampf aufweist, der aus dem LCO₂-Nachstrom erhalten wird, und einer Verdichtung unterzogen wird, bevor er zu dem Tanker zuröckgeföhrt wird.

5. Verfahren zum Entladen von LCO₂-Fracht von einem LCO₂-Tanker (30) in einen LCO₂-Zwischenspeichertank (40) an einem LCO₂-Empfangstermi-
- nal (100) nach Anspruch 4, das zusätzlich die folgenden Schritte aufweist:
 - ix.) Verdampfen eines verbleibenden nicht verdampften Anteils des zumindest teilweise verdampften LCO₂-Nachstroms nach dem Wärmeaustausch in Schritt (vii);

wobei in Schritt (iv.) der CO₂-Dampf von dem Terminal, der verdichtet und zu dem LCO₂-Tanker (30) zurückgeführt wird, den resultierenden CO₂-Dampf von Schritt (ix.) aufweist.

6. Verfahren nach Anspruch 4 oder 5, das zusätzlich den folgenden Schritt aufweist:
x.) nach dem Wärmeaustausch in Schritt (vii.) Abtrennen und Leiten eines verbleibenden nicht verflüssigten gasförmigen Anteils aus dem Abdampf-gas-Strom in einen LCO₂-Strom, der aus dem LCO₂-Zwischenspeichertank (40) entnommen und zu einer unterirdischen Langzeitspeichereinrichtung (120) befördert wird.

Revendications

1. Système (50) destiné à décharger une cargaison de LCO₂ d'un navire de transport de LCO₂ (30) vers un réservoir de stockage de LCO₂ intermédiaire (40) au niveau d'un terminal de réception de LCO₂ (100), lequel système évite une contamination croisée de cargaison d'un navire de transport de LCO₂ (30) à un autre, ledit système comprenant :

- un réservoir de stockage de LCO₂ intermédiaire (40) ;
- une sortie de gaz d'évaporation (60) du réservoir de stockage de LCO₂ intermédiaire (40) configurée pour extraire du gaz d'évaporation du réservoir de stockage de LCO₂ intermédiaire (40) ;
- un conduit d'importation de cargaison de LCO₂ (1, 10) raccordé au réservoir de stockage de LCO₂ intermédiaire (40) configuré pour recevoir un écoulement d'importation de cargaison de LCO₂ à partir du navire de transport de LCO₂ (30) ;
- un conduit de renvoi de vapeur de CO₂ (4, 5, 6, 7, 8, 9) configuré pour être raccordé au navire de transport de LCO₂ (30) et pour renvoyer, à partir du système (50), de la vapeur de CO₂ vers le navire de transport de LCO₂ (30) ;
- une sortie de LCO₂ (70) depuis le réservoir de stockage de LCO₂ intermédiaire (40) configurée pour décharger le LCO₂ du réservoir de stockage de LCO₂ intermédiaire (40) ;

caractérisé en ce que ledit système comprend en outre,

- un conduit d'écoulement glissant de LCO₂ (2) raccordé au conduit d'importation de cargaison de LCO₂ (1) configuré pour extraire un écoulement glissant de LCO₂ à partir du conduit d'importation de cargaison de LCO₂ (1) ;
- une vanne de réduction de pression (A) rac-

cordée au conduit d'écoulement glissant de LCO₂ (2) configurée pour recevoir l'écoulement glissant de LCO₂ ayant une première température (T1) et pour délivrer un écoulement au moins partiellement vaporisé de LCO₂ ayant une seconde température plus basse (T2) ;

- un conduit d'écoulement partiellement vaporisé (3) raccordé à la vanne de réduction de pression (A) configuré pour recevoir l'écoulement au moins partiellement vaporisé de LCO₂ ayant une seconde température plus basse (T2) ;

- un conduit de gaz d'évaporation (11) raccordé à la sortie de gaz d'évaporation (60) ;

- un premier échangeur de chaleur (B) raccordé respectivement au conduit d'écoulement partiellement vaporisé (3) et au conduit de gaz d'évaporation (11), ledit échangeur de chaleur étant configuré, respectivement, pour recevoir l'écoulement au moins partiellement vaporisé de LCO₂ ayant la seconde température plus basse (T2), pour recevoir le gaz d'évaporation extrait de la sortie de gaz d'évaporation (60), pour transférer de la chaleur du gaz d'évaporation vers l'écoulement au moins partiellement vaporisé de LCO₂ ayant la seconde température plus basse (T2), pour délivrer une fraction reliquifiée du gaz d'évaporation et pour délivrer un écoulement au moins partiellement vaporisé de LCO₂ ;

- un conduit de fraction reliquifiée (12, 15) raccordé au réservoir de stockage de LCO₂ intermédiaire (40) configuré pour recevoir la fraction reliquifiée sortant du premier échangeur de chaleur (B) ;

- dans lequel le conduit de renvoi de vapeur de CO₂ (4, 5, 6, 7, 8, 9) est en outre configuré pour recevoir de la vapeur de CO₂ issue de l'écoulement au moins partiellement vaporisé de LCO₂ ayant la seconde température plus basse (T2) ; et

- un compresseur de renvoi de vapeur (F) disposé le long du conduit de renvoi de vapeur (4, 5, 6, 7, 8, 9), configuré pour comprimer la vapeur de CO₂ à renvoyer vers le navire de transport de LCO₂ (30).

2. Système (50) selon la revendication 1, comprenant en outre

- un moyen (C, D, E) disposé le long du conduit de renvoi de vapeur de CO₂ (4, 5, 6, 7, 8, 9), configuré pour vaporiser une fraction non vaporisée restante de l'écoulement au moins partiellement vaporisé de LCO₂ sortant du premier échangeur de chaleur (B).

3. Système (50) selon la revendication 1 ou la reven-

dication 2, comprenant en outre

- une pompe d'injection (I) raccordée par le biais d'un conduit (16) à la sortie de LCO₂ (70) du réservoir de stockage de LCO₂ intermédiaire (40) configurée pour recevoir du LCO₂ extrait du réservoir de stockage de LCO₂ intermédiaire (40), et pour éjecter un écoulement de LCO₂ comprimé à injecter dans un pipeline (110) raccordé à une installation de stockage à long terme souterraine (120) ; et
 - un conduit de fraction gazeuse restante (12, 13, 14) et un moyen (G, H) disposé le long dudit conduit de fraction gazeuse restante (12, 13, 14) configuré pour recevoir, séparer du conduit de fraction reliquéfiée (12, 15), et comprimer une fraction gazeuse restante sortant du premier échangeur de chaleur (B) issue du gaz d'évaporation, et pour injecter la fraction gazeuse comprimée obtenue du gaz d'évaporation en un écoulement de LCO₂ comprimé à injecter dans un pipeline (110) raccordé à une installation de stockage à long terme souterraine (120).

4. Procédé de déchargement d'une cargaison de LCO₂ d'un navire de transport de LCO₂ (30) vers un réservoir de stockage de LCO₂ intermédiaire (40) au niveau d'un terminal de réception de LCO₂ (100), évitant une contamination croisée de cargaison d'un navire de transport de LCO₂ (30) à un autre, ledit procédé comprenant les étapes suivantes consistant à :

i.) recevoir un écoulement principal de LCO₂ d'un navire de transport de LCO₂ (30) et diriger l'écoulement principal vers un réservoir de stockage de LCO₂ intermédiaire (40) ;
 ii.) extraire du LCO₂ d'une sortie de LCO₂ (70) du réservoir de stockage de LCO₂ intermédiaire (40) ;
 iii.) extraire un écoulement de gaz d'évaporation de la sortie de gaz d'évaporation (60) du réservoir de stockage de LCO₂ intermédiaire (40) ;
 iv.) renvoyer de la vapeur de CO₂ du terminal (100) en retour vers le navire de transport de LCO₂ (30),

caractérisé en ce que le procédé comprend en outre les étapes suivantes consistant à :

v.) extraire, de l'écoulement principal de LCO₂, un écoulement glissant de LCO₂ ;
 vi.) soumettre l'écoulement glissant extrait de LCO₂ ayant une première température (T1) à une pression réduite, vaporisant ainsi partiellement l'écoulement glissant de LCO₂ extrait ayant une première température (T1) de façon à produire un écoulement glissant de LCO₂ au

moins partiellement vaporisé ayant une seconde température plus basse (T2) ;

vii.) soumettre l'écoulement de gaz d'évaporation extrait à un échange de chaleur avec l'écoulement glissant de LCO₂ au moins partiellement vaporisé ayant la seconde température plus basse (T2), liquéfiant ainsi partiellement ou complètement l'écoulement de gaz d'évaporation en une fraction liquéfiée ;

viii.) renvoyer la fraction liquéfiée obtenue vers le réservoir de stockage de LCO₂ intermédiaire (40) ;

dans lequel, à l'étape (iv.), la vapeur de CO₂ provenant du terminal (100) qui est renvoyée vers le navire de transport de LCO₂ (30) comprend un écoulement de vapeur de CO₂ obtenu à partir de l'écoulement glissant de LCO₂ et est soumise à une compression avant d'être renvoyée vers le navire.

5. Procédé de déchargement d'une cargaison de LCO₂ d'un navire de transport de LCO₂ (30) vers un réservoir de stockage de LCO₂ intermédiaire (40) au niveau d'un terminal de réception de LCO₂ (100) selon la revendication 4, comprenant en outre l'étape suivante consistant à :

ix.) vaporiser une fraction non vaporisée restante de l'écoulement glissant de LCO₂ au moins partiellement vaporisé après l'échange de chaleur de l'étape (vii) ;
 dans lequel, à l'étape (iv.), la vapeur de CO₂ provenant du terminal qui est comprimée et renvoyée vers le navire de transport de LCO₂ (30) comprend la vapeur de CO₂ obtenue à l'étape (ix.).

6. Procédé selon la revendication 4 ou la revendication 5, comprenant en outre l'étape consistant à :

x.) après l'échange de chaleur de l'étape (vii.), séparer et diriger une fraction gazeuse non liquéfiée restante de l'écoulement de gaz d'évaporation en un écoulement de LCO₂ qui est extrait du réservoir de stockage de LCO₂ intermédiaire (40) et qui est transporté vers une installation de stockage à long terme souterraine (120).

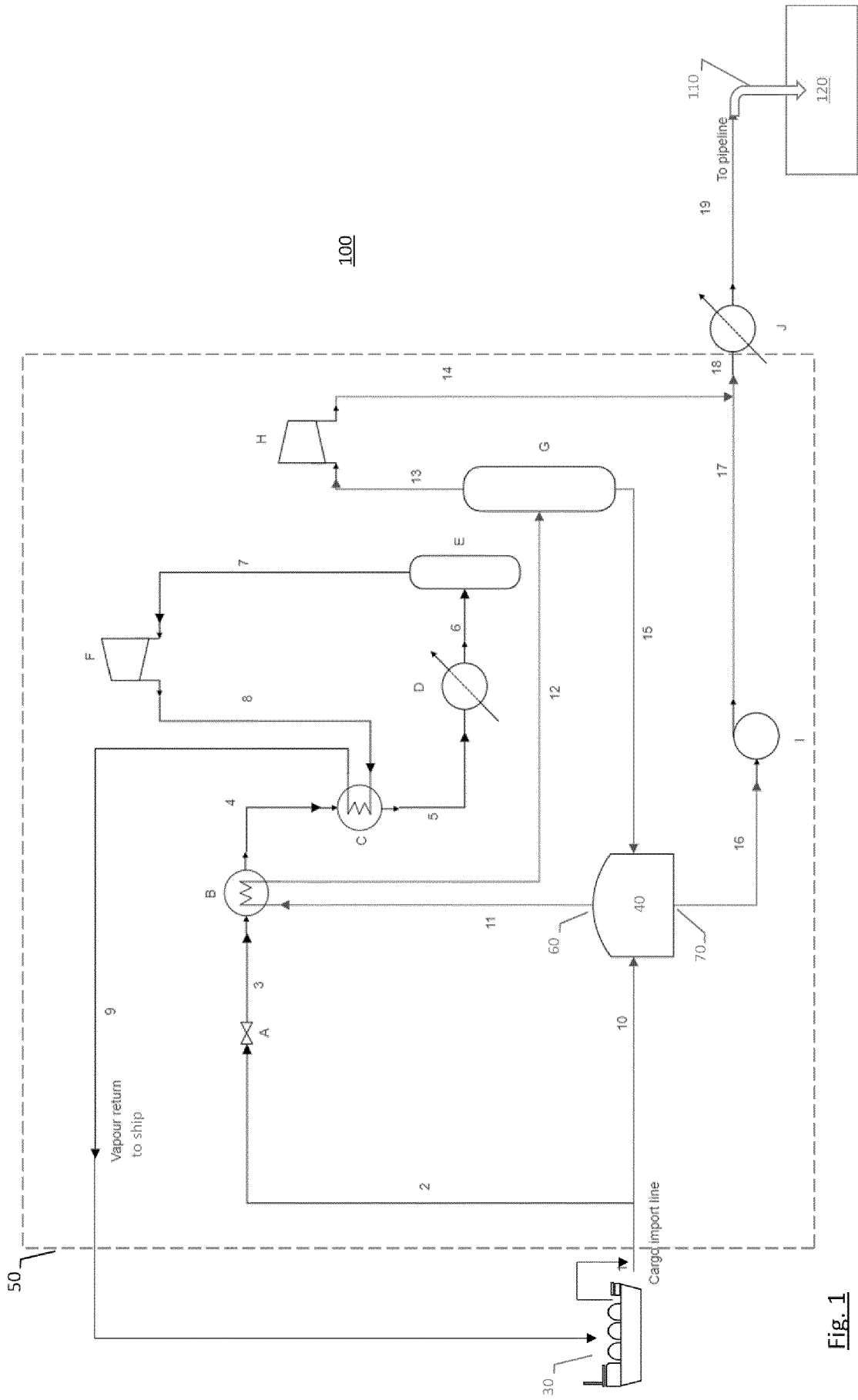


Fig. 1

REFERENCES CITED IN THE DESCRIPTION

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Non-patent literature cited in the description

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