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(54) **SYSTEM AND METHOD FOR REFRIGERATION OF CONTENTS OF AN LCO2 INTERMEDIATE STORAGE TANK AT A CO2 RECEIVING TERMINAL**

(57) A system **110** and a method for refrigeration of the contents of an intermediate liquid $CO_2$ ($LCO_2$) storage tank **10** at a $CO_2$ receiving terminal during offloading of $LCO_2$ into the storage tank are disclosed. The invention uses vaporisation of $LCO_2$ for vapour return to ship to provide for refrigeration of a fluid stream being withdrawn from storage tank **10**, which fluid stream, after refrigeration thereof, is returned to the storage tank **10**.

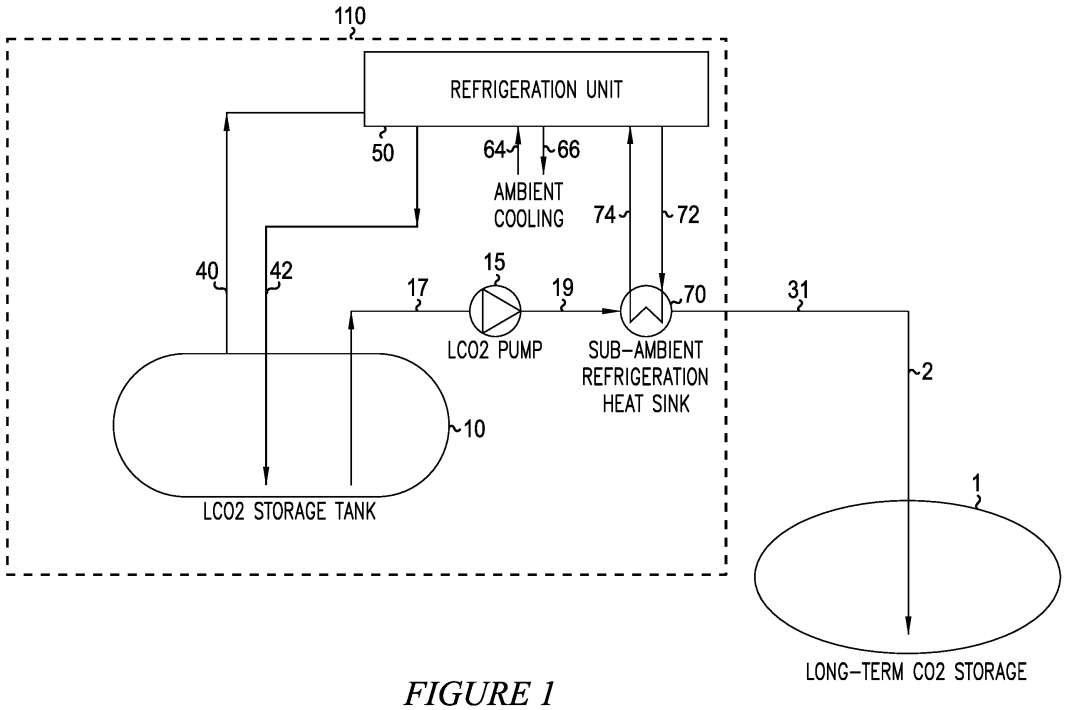


*FIGURE 1*



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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 and method for refrigeration of the contents of an intermediate liquid $CO_2$ ($LCO_2$) storage tank at a $CO_2$ receiving terminal during injection of $LCO_2$ into a pipeline connected to a long-term storage. The invention an injection stream being injected into a pipeline connected to a long-term storage to provide for refrigeration of a fluid stream being withdrawn from storage tank, which fluid stream, after refrigeration thereof, is returned to the storage tank.

### BACKGROUND ART

**[0002]** In a $CO_2$ terminal for Carbon Capture and Storage (CCS), intermediate storage is provided for the liquefied $CO_2$ ($LCO_2$) prior to injection into a reservoir for long-term storage. Captured and liquefied carbon dioxide can be transported in the liquid phase ($LCO_2$) from various locations and customers by ship to $CO_2$ receiving terminals. 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.

**[0003]** Handling of liquefied gases, e.g. $LCO_2$, below ambient temperature often requires mechanical refrigeration to maintain or lower the pressure in an intermediate storage, without venting the liquefied gas to atmosphere or another location. Natural heat ingress from the warmer ambient surroundings into the colder intermediate storage causes a pressure rise and/or generation of boil-off gas. In order to counteract the natural heat ingress, refrigeration could be applied. Refrigeration could also be applied in excess of the natural heat ingress to actively reduce storage pressure. However, high refrigeration duties imply high power input requirements.

**[0004]** It would be desirable to be able to reduce the power input requirements for the refrigeration required in a $CO_2$ terminal to counteract the natural heat ingress.

**[0005]** Accordingly, it is an object of the present invention to provide a system and a method enabling reducing the power input requirements for refrigeration in a $CO_2$ terminal to counteract the natural heat ingress.

### SUMMARY OF THE INVENTION

**[0006]** The present invention uses cold $LCO_2$ present in the $CO_2$ terminal outside of the intermediate storage as a heat sink to aid the refrigeration. More particularly, the invention uses an injection stream of $LCO_2$ that is being injected into a pipeline connected to a long-term storage. The cold $LCO_2$ that is being injected into the pipeline does not need to stay cold, and can thus act as a heat sink to aid refrigeration. According to the present invention, $LCO_2$ that will be heated even without the invention as part of the normal operation of the terminal is used as a heat sink, thereby making use of a waste low-temperature resource.

**[0007]** Accordingly, in one aspect the invention relates to a system **110** configured to refrigerate $LCO_2$ contained in an intermediate $LCO_2$ storage tank **10** at a $CO_2$ receiving terminal, the system comprising: an intermediate $LCO_2$ storage tank **10;** a fluid withdrawal conduit **40,** connected to the intermediate $LCO_2$ storage tank **10** configured to withdrawing a fluid stream from the intermediate $LCO_2$ storage tank **10;** an $LCO_2$ discharge conduit **17, 19, 31,** one end of which is connected to the intermediate $LCO_2$ storage tank **10,** and the other end is connected to a pipeline **2** connected to a long-term storge **1,** said discharge conduit being configured to withdraw an $LCO_2$ discharge stream from the intermediate $LCO_2$ storage tank and to lead the stream to the pipeline **2;** a first $LCO_2$ pump **15** arranged along the $LCO_2$ discharge conduit **17, 19, 31;** a refrigeration unit **50** connected to the fluid withdrawal conduit **40** configured to refrigerate the withdrawn fluid stream from the intermediate $LCO_2$ storage tank **10;** a fluid return conduit **42** connecting the refrigeration unit **50** with the intermediate $LCO_2$ storage tank **10** configured to convey a refrigerated and/or liquefied fluid stream from the refrigeration unit **50** to the intermediate $LCO_2$ storage tank **10,** a sub-ambient refrigeration heat sink **70** arranged along the $LCO_2$ discharge conduit **17, 19, 31** at a location downstream of the first $LCO_2$ pump **15** configured to transfer heat from a refrigerant stream exiting the refrigeration unit **50** to the $LCO_2$ discharge stream; a refrigerant heating conduit **72** fluidly connecting the refrigeration unit **50** with the sub-ambient refrigeration heat sink **70** configured to convey to the sub-ambient refrigeration heat sink **70** the refrigerant stream exiting the refrigeration unit **50;** and, a refrigerant return conduit **74** fluidly connecting the refrigeration unit **50** with the sub-ambient refrigeration heat sink **70** configured to return to the refrigeration unit **50** the refrigerant stream.

**[0008]** In another aspect, the invention relates to a method for refrigeration of the contents of an intermediate $LCO_2$ storage tank **10** at a $CO_2$ receiving terminal during injection of $LCO_2$ into a pipeline **2** connected to a long-term storage **1,** said method comprising the following steps: **A** discharging a stream of $LCO_2$ from an intermediate $LCO_2$ storage tank **10** to be injected into a pipeline **2** connected to a long-term $CO_2$ storage; **B** subjecting the stream of $LCO_2$ from step **A** to pumping in a first pumping stage **15;** C transferring heat from a refrigerant stream to the $LCO_2$ stream from step **B;**

**D** withdrawing a fluid stream **40** from the intermediate $LCO_2$ storage tank **10; E** refrigerating the withdrawn fluid stream from step **D,** thereby liquefying the withdrawn fluid stream and/or cooling the withdrawn fluid stream; and, **F** returning the fluid stream from step **E** to the storage tank **10,** wherein, in step **E,** heat from the withdrawn fluid stream **40** is transferred to the refrigerant stream to be used as a heat source for the refrigeration of step **E,** and the $LCO_2$ stream from step **B** is used as a heat sink for the refrigeration of step **E.**

**[0009]** The invention can reduce the power requirements for the refrigeration by about 50% compared to using an ambient heat sink alone.

**[0010]** Further embodiments and advantages of the invention will be apparent from the following detailed description and appended claims.

**[0011]** In the present disclosure, same reference numeral is used both to denote the conduit and the stream flowing therein. For example, reference numeral **42** is used to both denote the fluid return conduit, and also to denote the fluid stream itself flowing in said conduit.

**[0012]** The term "long-term" as used herein denotes a storage intended to be permanent.

## BRIEF DESCRIPTION OF THE ATTACHED DRAWING

**[0013]**

Figure 1 shows an embodiment of the inventive system **110** as indicated by the dashed line which can be implemented into an $CO_2$ receiving terminal. The inventive system **110** in its most generic embodiment does not include the ambient cooling **64, 66,** which in a preferred embodiment can be attached to the refrigeration unit **50; 51.**

Figure 2 shows an embodiment of the inventive system **110** including a detailed embodiment of the refrigeration unit **51.**

## DETAILED DESCRIPTION OF THE INVENTION

**[0014]** The present invention provides refrigeration of an intermediate $LCO_2$ storage tank **10** during discharge from the storage tank of an $LCO_2$ stream to be injected into a pipeline connected with a long-term storage **1.** As shown in **Fig. 1,** the cold $LCO_2$ from the intermediate storage that is being injected into the pipeline, can be used as an additional, sub-ambient heat sink for the refrigeration, since the injected $LCO_2$ does not need to stay cold.

**[0015]** By providing a sub-ambient heat sink for the refrigeration system, the temperature difference between the heat source (fluid **40** from the intermediate $LCO_2$ storage tank **10)** and the heat sink (fluid **19** that is being injected into the long-term $CO_2$ reservoir **1** via pipeline **2**) is reduced compared to using only an ambient heat sink **64, 66,** which inherently improves refrigeration efficiency.

**[0016]** For operational reasons, it may be useful to bring the pressure in the intermediate storage tank **10** down even further than just through injecting the liquid while not loading, e.g. in preparation to receive a large cargo "parcel" where no vapour return at all is allowed. For example, it may be desirable for a ship **30** to reduce its pressure prior to leaving the terminal, and therefore not accept vapour return.

**[0017]** The refrigeration unit could, in principle, use any sort of refrigeration, including mechanical, thermoelectric, or absorptive refrigeration, mechanical refrigeration being generally preferred due to the current state of the art. The invention provides a lower-temperature heat sink compared to the ambient, and thereby increases refrigeration efficiency.

**[0018]** The ambient fluid used for ambient cooling could be sea water, fresh water and/or air.

**[0019]** The invention can reduce the power requirements for the refrigeration by about 50% compared to using ambient heat sinks alone.

## LIST OF REFERENCE SIGNS USED

**[0020]**

| | |
|---|---|
| 1 | long-term $CO_2$ storage |
| 2 | pipeline |
| 10 | intermediate $LCO_2$ storage tank |
| 15 | first $LCO_2$ pump |
| 17, 19, 31 | discharge conduit |
| 30 | $LCO_2$ carrier ship |
| 40 | fluid withdrawal conduit |
| 42 | fluid return conduit |

| | |
|---|---|
| 50; 51 | refrigeration unit |
| 64 | ambient cooling inlet |
| 66 | ambient cooling outlet |
| 70 | sub-ambient refrigeration heat sink |
| 72 | refrigerant heating conduit |
| 74 | refrigerant return conduit |
| 81, 83, 85, 87 | refrigerant medium conduit |
| 74, 85, 87, 81, 83, 72 | closed refrigerant loop |
| 91 | refrigerant compressor |
| 93 | desuperheater |
| 95 | refrigerant receiver |
| 97 | expansion valve |
| 99 | evaporator |
| 110 | system |

## Claims

1. A system (110) configured to refrigerate $LCO_2$ contained in an intermediate $LCO_2$ storage tank (10) at a $CO_2$ receiving terminal, the system comprising:

   - an intermediate $LCO_2$ storage tank (10);
   - a fluid withdrawal conduit (40) connected to the intermediate $LCO_2$ storage tank (10) configured to withdrawing a fluid stream from the intermediate $LCO_2$ storage tank (10);
   - an $LCO_2$ discharge conduit (17, 19, 31), one end of which is connected to the intermediate $LCO_2$ storage tank (10), and the other end is connected to a pipeline (2) connected to a long-term storge (1), said discharge conduit being configured to withdraw an $LCO_2$ discharge stream from the intermediate $LCO_2$ storage tank and to lead the stream to the pipeline (2);
   - a first $LCO_2$ pump (15) arranged along the $LCO_2$ discharge conduit (17, 19, 31);
   - a refrigeration unit (50; 51) connected to the fluid withdrawal conduit (40) configured to refrigerate the withdrawn fluid stream from the intermediate $LCO_2$ storage tank (10);
   - a fluid return conduit (42) connecting the refrigeration unit (50; 51) with the intermediate $LCO_2$ storage tank (10) configured to convey a refrigerated and/or liquefied fluid stream from the refrigeration unit (50; 51) to the intermediate $LCO_2$ storage tank (10),
   - a sub-ambient refrigeration heat sink (70) arranged along the $LCO_2$ discharge conduit (17, 19, 31) at a location downstream of the first $LCO_2$ pump (15) configured to transfer heat from a refrigerant stream exiting the refrigeration unit (50; 51) to the $LCO_2$ discharge stream;
   - a refrigerant heating conduit (72) fluidly connecting the refrigeration unit (50; 51) with the sub-ambient refrigeration heat sink (70) configured to convey to the sub-ambient refrigeration heat sink (70) the refrigerant stream exiting the refrigeration unit (50; 51); and,
   - a refrigerant return conduit (74) fluidly connecting the refrigeration unit (50; 51) with the sub-ambient refrigeration heat sink (70) configured to return to the refrigeration unit (50; 51) the refrigerant stream.

2. The system (110) of claim 1, wherein the refrigeration unit (50; 51) additionally comprises:

   - an ambient cooling inlet (66) configured to enter a flow of an ambient fluid into the refrigeration unit (50; 51); and
   - an ambient cooling outlet (64), configured to exit a flow of heated ambient fluid from the refrigeration unit (50; 51).

3. The system (110) of claim 2, wherein the refrigeration unit (50; 51) comprises:

   - a refrigerant medium conduit (81, 83, 85, 87), connected to the refrigerant heating conduit (72), and to the refrigerant return conduit (74);
   - an evaporator (99) arranged along the refrigerant medium conduit (81, 83, 85, 87) fluidly connected to the fluid withdrawal conduit (40), and to the fluid return conduit (42) configured to receive the withdrawn fluid stream (40), to transfer heat from the latter to the refrigerant medium stream in the evaporator (99), and to exit a cooled withdrawn fluid stream (42);
   - a refrigeration compressor (91) arranged along the refrigerant medium conduit (81, 83, 85, 87) downstream of the evaporator (99) configured to compress a refrigerant medium stream exiting the evaporator (99), and to

exit a compressed stream of refrigerant medium;
- a desuperheater (93) arranged along the refrigerant medium conduit (81, 83, 85, 87) downstream of the refrigeration compressor (91) configured to transfer heat from the compressed refrigerant medium stream to a flow of ambient fluid (64, 66), and to exit a cooled compressed refrigerant medium stream to the sub-ambient refrigeration heat sink (70);
- receiver (95) arranged along the refrigerant medium conduit (81, 83, 85, 87) downstream of the sub-ambient refrigeration heat sink (70) configured to receive the cooled compressed refrigerant medium stream;
- an expansion valve (97) arranged along the refrigerant medium conduit (81, 83, 85, 87) downstream of the receiver (95) fluidly connected with the evaporator (99) configured to exit an expanded stream of refrigerant medium to the evaporator (99).

**4.** A method for refrigeration of the contents of an intermediate $LCO_2$ storage tank (10) at a $CO_2$ receiving terminal during injection of $LCO_2$ into a pipeline (2) connected to a long-term storage (1), said method comprising the following steps:

A) discharging a stream of $LCO_2$ from an intermediate $LCO_2$ storage tank (10) to be injected into a pipeline (2) connected to a long-term $CO_2$ storage;
B) subjecting the stream of $LCO_2$ from step A to pumping in a first pumping stage (15);
C) transferring heat from a refrigerant stream to the $LCO_2$ stream from step B;
D) withdrawing a fluid stream (40) from the intermediate $LCO_2$ storage tank (10);
E) refrigerating the withdrawn fluid stream from step D, thereby liquefying the withdrawn fluid stream and/or cooling the withdrawn fluid stream; and,
F) returning the fluid stream from step E to the storage tank (10);

wherein, in step E, heat from the withdrawn fluid stream (40) is transferred to the refrigerant stream to be used as a heat source for the refrigeration of step E, and the $LCO_2$ stream from step B is used as a heat sink for the refrigeration of step E.

**5.** The method for refrigeration of claim 4, additionally comprising the step:

G) transferring heat to an ambient fluid from the refrigerant stream.

**6.** The method of claim 5, wherein the refrigerant is circulated in a closed refrigerant loop (74, 85, 87, 81, 83, 72), and wherein the refrigerant is vaporised in step E, said method additionally comprising the steps:

H) compressing the vaporised refrigerant stream from step E;
wherein, in step G, heat is transferred from the compressed vaporised refrigerant of step H; wherein, in step C, the compressed vaporised refrigerant stream from step H is condensed;
I) subjecting the condensed refrigerant stream from step C to expansion,
wherein, in step E, the refrigeration is achieved by vaporisation of the expanded condensed refrigerant stream from step I.

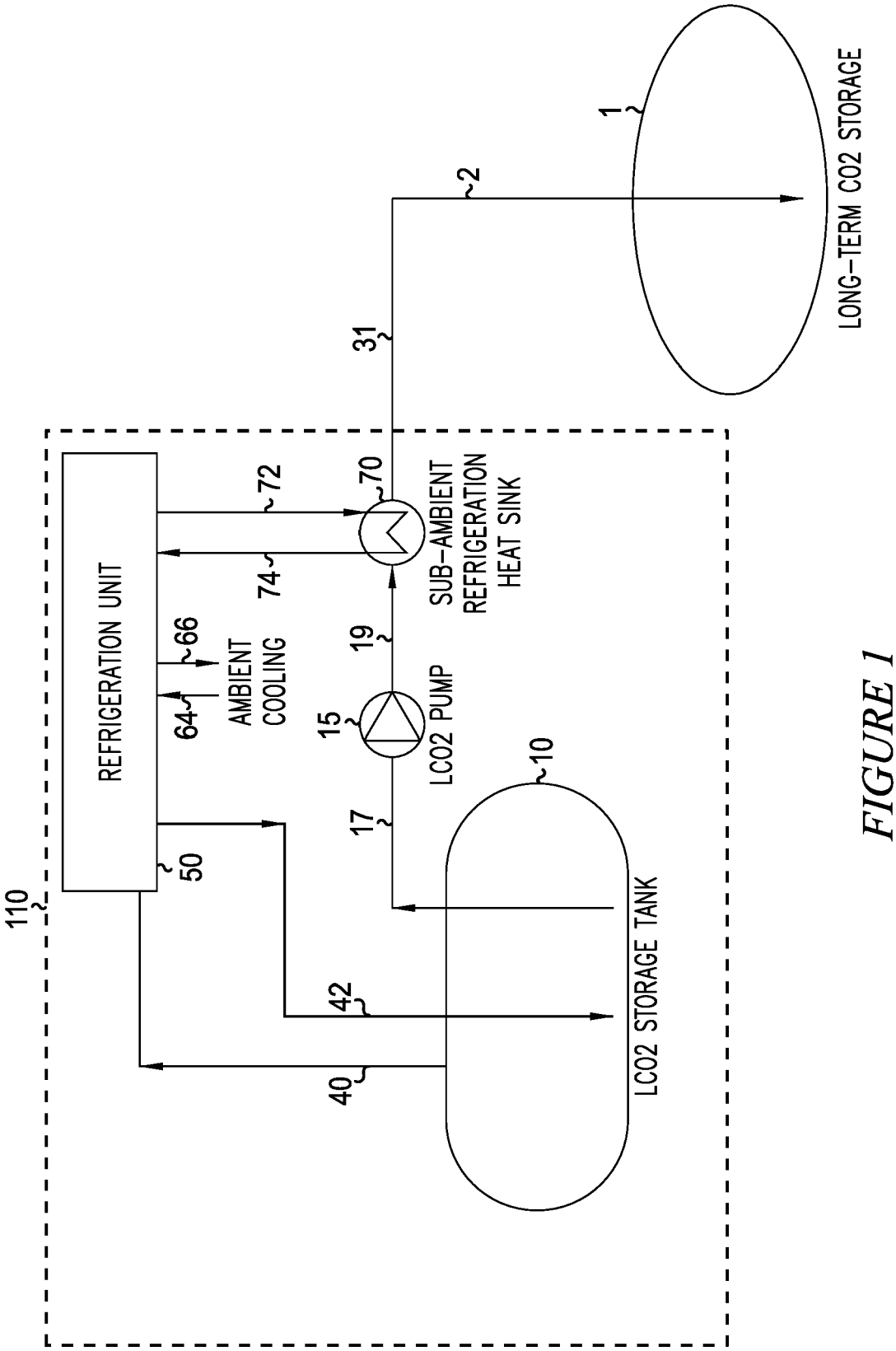
110
REFRIGERATION UNIT
50
64
66
AMBIENT COOLING
72
74
70
SUB-AMBIENT REFRIGERATION HEAT SINK
19
15
LCO2 PUMP
17
10
LCO2 STORAGE TANK
42
40
31
2
1
LONG-TERM CO2 STORAGE

*FIGURE 1*

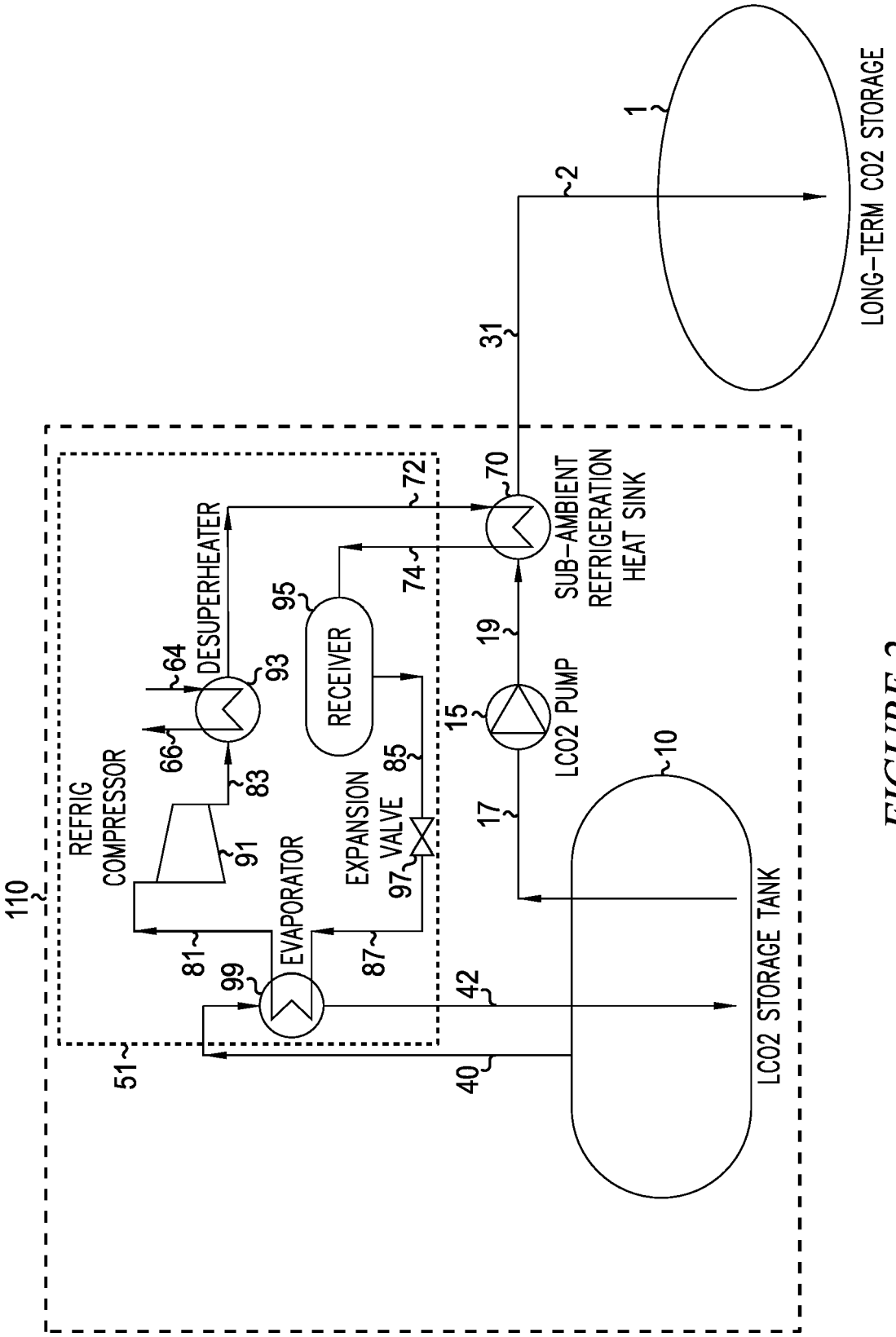
110
REFRIG COMPRESSOR
91
83
66
64
DESUPERHEATER
93
95
RECEIVER
74
72
70
SUB-AMBIENT REFRIGERATION HEAT SINK
19
15
LCO2 PUMP
17
10
LCO2 STORAGE TANK
85
EXPANSION VALVE
97
81
99
EVAPORATOR
87
42
40
51
31
2
1
LONG-TERM CO2 STORAGE

*FIGURE 2*

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# EUROPEAN SEARCH REPORT

Application Number
EP 23 15 6843

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| Place of search | Date of completion of the search | Examiner |
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| Munich | 20 July 2023 | Fritzen, Claas |

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