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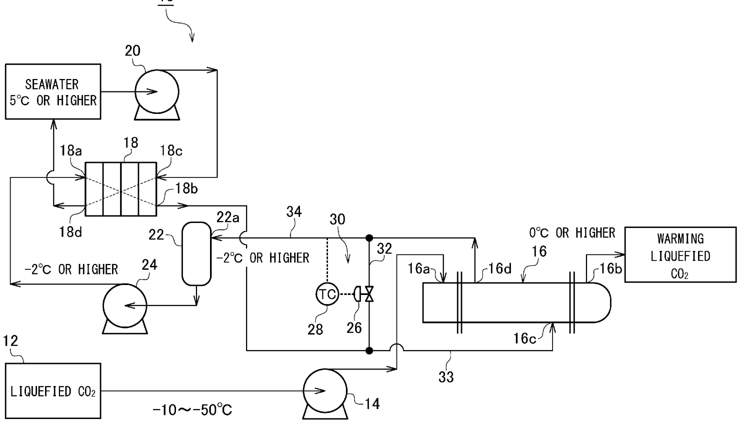
(54) EQUIPMENT FOR WARMING LIQUEFIED CARBON DIOXIDE AND METHOD FOR WARMING LIQUEFIED CARBON DIOXIDE

(57) Liquefied carbon dioxide warming equipment 10 is provided with a heat medium warmer 18 that receives a supply of seawater and a heat medium and warms the heat medium by heat exchange with the seawater, a warming heat exchanger 16 that warms the liquefied carbon dioxide to a predetermined temperature by heat exchange with the heat medium warmed by the heat medium warmer 18, and a heat medium temperature controller 30 that performs control so that a temperature of the heat medium supplied to the heat medium warmer 18 is equal to or higher than a freezing temperature of the seawater.

FIG. 2



EP 4 357 232 A1

Description

TECHNICAL FIELD

[0001] The present invention relates to warming equipment and a warming method for liquefied carbon dioxide (liquefied CO_2) for carbon capture and storage (CCS).

BACKGROUND ART

[0002] Carbon capture and storage (CCS) is a countermeasure against global warming involving capturing CO_2 from a CO_2 generation source (for example, combustion exhaust gas from a coal-fired power plant) by a chemical absorption technique or the like, then compresses the CO_2 to inject and store the CO_2 in an underground aquifer (reservoir) shielded by a bedrock or the like in a supercritical state. (See, for example, Patent Literature 1 and 2 regarding CCS.)

[0003] There are various methods for CCS, and one of them is a liquefied carbon dioxide transport and injection system. In this method, the separated and captured CO_2 is compressed and liquefied, temporarily stored in a tank on land in the form of liquefied carbon dioxide, loaded on a liquefied carbon dioxide transport ship from the tank, and transported by ship to a storage site. At the storage site, the liquefied carbon dioxide is injected from the liquefied carbon dioxide transport ship into an aquifer below the seafloor.

PRIOR ART DOCUMENTS

Patent Literature

[0004]

Patent Literature 1: JP 2011-31154
Patent Literature 2: JP 2012-72012

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0005] To prevent the surrounding water from freezing and blockages due to the formation of CO_2 hydrates when a liquefied carbon dioxide is injected into a reservoir (aquifer), the liquefied carbon dioxide (for example, -10°C/2.289 MPa to -50°C/0.684 MPa) is pressurized to a predetermined pressure (10 MPa or higher), then warmed to 0°C or more to perform injection.

[0006] While some kind of heat source is required to warm the liquefied carbon dioxide, usable heat sources are limited when considering the condition of being on a liquefied carbon dioxide transport ship. A method of generating hot water by a hot water boiler and warming the liquefied carbon dioxide by the heat exchange between the hot water and the liquefied carbon dioxide has been considered as one method. However, with this method, there is a problem in that since a large amount of fuel is consumed in the hot water boiler, there is an increase in cost, and further, CO_2 is discharged when fuel is consumed.

[0007] The present invention has been made in view of such circumstances, and an object thereof is to provide a technique capable of suitably warming liquefied carbon dioxide for CCS.

SOLUTION TO PROBLEM

[0008] In order to solve the above problem, liquefied carbon dioxide warming equipment according to an aspect of the present invention is provided with a heat medium warmer that receives a supply of seawater and a heat medium and warms the heat medium by heat exchange with the seawater, a warming heat exchanger that warms the liquefied carbon dioxide to a predetermined temperature by heat exchange with the heat medium warmed by the heat medium warmer, and a heat medium temperature controller that performs control so that the temperature of the heat medium supplied to the heat medium warmer is equal to or higher than a freezing temperature of the seawater.

[0009] Another aspect of the present invention is a liquefied carbon dioxide warming method. This method includes supplying seawater and a heat medium to a heat medium warmer, warming the heat medium by heat exchange with the seawater using the heat medium warmer, warming the liquefied carbon dioxide to a predetermined temperature by heat exchange with the heat medium, and performing control so that the temperature of the heat medium supplied to the heat medium warmer is equal to or higher than a freezing temperature of the seawater.

ADVANTAGEOUS EFFECTS OF INVENTION

[0010] According to the present invention, it is possible to provide a technique capable of suitably warming liquefied carbon dioxide for CCS.

BRIEF DESCRIPTION OF DRAWINGS

[0011]

[Fig.1] Fig. 1 is a diagram showing a schematic flow of CCS in which liquefied carbon dioxide warming equipment according to an embodiment of the present invention is used.
[Fig.2] Fig. 2 is a view for describing liquefied carbon dioxide warming equipment according to one embodiment of the present invention.
[Fig.3] Fig. 3 is a view for describing liquefied carbon dioxide warming equipment according to another embodiment of the present invention.

DESCRIPTION OF EMBODIMENTS

[0012] Hereinafter, the present invention will be described based on preferred embodiments with reference to the drawings. The following configurations are intended as an illustration for understanding the present disclosure; the scope of the present disclosure is defined only by the appended claims. The same or equivalent constituent elements and members illustrated in the respective drawings are denoted by the same reference numerals, and redundant descriptions will be omitted as appropriate. In addition, the dimensions of the members in each drawing are shown enlarged or reduced as appropriate in order to facilitate understanding. Moreover, in each drawing, some members not important for describing the embodiment are omitted.

[0013] Fig. 1 is a diagram showing a schematic flow of CCS using liquefied carbon dioxide warming equipment according to one embodiment of the present invention. Fig. 1 shows CCS in a liquefied carbon dioxide transport and injection system. Other examples of CCS include a submarine pipeline system and an extended reach drilling (ERD) system.

[0014] In CCS, CO_2 is separated and captured from a CO_2 generation source such as combustion exhaust gas from a coal-fired power plant using, for example, a chemical absorption technique or the like. Thereafter, the captured CO_2 is compressed and liquefied, then stored in a tank on land in the form of liquefied carbon dioxide. The liquefied carbon dioxide is loaded on a liquefied carbon dioxide transport ship 100 from the tank and transported by ship to a storage site 102 on a sea 110.

[0015] The liquefied carbon dioxide loaded on the liquefied carbon dioxide transport ship 100 is pressurized and warmed by liquefied carbon dioxide warming equipment 10 installed on the liquefied carbon dioxide transport ship 100, then injected from the liquefied carbon dioxide transport ship 100 into an aquifer 114 at the storage site 102. The aquifer 114 is a layer further below a blocking layer 112 located below the seafloor.

[0016] In CCS shown in Fig. 1, the liquefied carbon dioxide is sent to a well head 106 installed on the seafloor via a flexible riser pipe (FRP) for connecting seafloor equipment. Thereafter, the liquefied carbon dioxide is sent to a Xmas tree 108 via a flow line 107 laid on the seafloor. A Xmas tree is a collection of valves that control the pressure of fluid produced from a well. In the Xmas tree 108, the liquefied carbon dioxide is injected into the aquifer 114.

[0017] In the above description, the liquefied carbon dioxide warming equipment 10 has been installed on the liquefied carbon dioxide transport ship 100, however the liquefied carbon dioxide warming equipment 10 may be installed on a bottom-mounted platform installed on the sea or a floating body (FSO: floating storage and offloading or buoy) moored on the sea.

[0018] Fig. 2 is a view for describing the liquefied carbon dioxide warming equipment 10 according to one embodiment of the present invention. The liquefied carbon dioxide warming equipment 10 is equipment that performs pressurization for injecting liquefied carbon dioxide (for example, -10°C/2.289 MPa to -50°C/0.684 MPa) transported by ship into a reservoir (aquifer) on the seafloor, and warming to prevent the surrounding water from freezing and blockages due to the formation of CO_2 hydrates when the liquefied carbon dioxide is injected into the reservoir.

[0019] Here, the injection conditions for CCS will be described.

(1) Injection pressure

[0020] While the injection pressure varies depending on the depth of the reservoir, permeability, and the strength of the shielding layer, it is generally represented by "static head + 3 MPa to a breaking pressure of the shielding layer" at the injection site. In the case of CCS in an underground reservoir below the seafloor, when considering an injection depth of 2000 m to 3000 m, the density of liquefied carbon dioxide, and pressure loss in the well, a suitable injection pressure is about 10 MPa to 13 MPa in the Xmas tree 108 on the seafloor (see Fig. 1).

(2) Injection temperature

[0021] When the liquefied carbon dioxide is injected into the reservoir (aquifer 114), it is necessary to perform injection by warming in order to prevent the surrounding water from freezing (0°C or higher) and blockages due to the formation of CO_2 hydrates (5°C or lower). When considering that blockages due to the formation of CO_2 hydrates did not occur when injecting at 0°C in actual examples of CCS in the past, the injection temperature of the liquefied carbon dioxide is preferably 0°C or higher.

[0022] As shown in Fig. 2, the liquefied carbon dioxide warming equipment 10 is provided with a storage tank 12, a booster pump 14, a warming heat exchanger 16, a heat medium warmer 18, a seawater pump 20, a heat medium drum 22, a heat medium pump 24, and a heat medium temperature controller 30.

[0023] The storage tank 12 stores the liquefied carbon dioxide (liquefied CO_2). The temperature of the liquefied carbon dioxide may be -10°C to -50°C, while the pressure of the liquefied carbon dioxide may be 2.289 MPa to 0.684 MPa. The liquefied carbon dioxide stored in the storage tank 12 is supplied to the booster pump 14.

[0024] The booster pump 14 pressurizes the liquefied carbon dioxide supplied from the storage tank 12 to a predetermined pressure (for example, 10 MPa or higher). The liquefied carbon dioxide pressurized by the booster pump 14 is supplied to the warming heat exchanger 16.

[0025] The warming heat exchanger 16 is a shell-and-tube heat exchanger in which a plurality of heat transfer tubes are housed in a cylindrical shell. In the present embodiment, the cylindrical shell and the heat transfer tubes of the warming heat exchanger are all made of general steel. The liquefied carbon dioxide from the booster pump 14 is supplied to a tube side of the warming heat exchanger 16. The liquefied carbon dioxide is input to a tube side inlet 16a of the warming heat exchanger 16 and output from a tube side outlet 16b. Meanwhile, the heat medium is supplied to a shell side of the warming heat exchanger 16. The heat medium is input to a shell side inlet 16c of the warming heat exchanger 16 via a line 33 and output from a shell side outlet 16d. The warming heat exchanger 16 performs heat exchange between the liquefied carbon dioxide supplied to the tube side and the heat medium supplied to the shell side to warm the liquefied carbon dioxide to a predetermined temperature (0°C or higher).

[0026] A heat medium (antifreeze liquid) that does not freeze even at the temperature (-10°C to -50°C) of the liquefied carbon dioxide supplied to the warming heat exchanger 16 is used as the heat medium. Examples of solutions that can be used as such a heat medium include an ethylene glycol aqueous solution, a propylene glycol aqueous solution, a mixed solution of the ethylene glycol aqueous solution and the propylene glycol aqueous solution, or a hydrocarbon compound solution. The content of the ethylene glycol, the propylene glycol, the hydrocarbon compound, and the like in each solution is set on the condition that the solution does not freeze at the temperature of the supplied liquefied carbon dioxide, and is set to, for example, 10 wt% or more of the ethylene glycol or 10 wt% or more of the propylene glycol. These solutions preferably contain a rust inhibitor.

[0027] The heat medium output from the shell side outlet 16d of the warming heat exchanger 16 is supplied to the heat medium drum 22 via a line 34. Thereafter, the heat medium is supplied to the heat medium warmer 18 by the heat medium pump 24.

[0028] The heat medium temperature controller 30 performs control such that the temperature of the heat medium supplied to the heat medium warmer 18 is equal to or higher than the freezing temperature (-2°C) of seawater. The heat medium temperature controller 30 is provided with a control valve 26 and a temperature sensor 28.

[0029] As shown in Fig. 2, the control valve 26 is installed in a bypass line 32 that bypasses the shell side inlet 16c and the shell side outlet 16d of the warming heat exchanger 16. That is, the bypass line 32 bypasses the line 33 connecting the heat medium outlet 18b of the heat medium warmer 18 and the shell side inlet 16c of the warming heat exchanger 16 and the line 34 connecting the shell side outlet 16d of the warming heat exchanger 16 and the inlet 22a of the heat medium drum 22.

[0030] The temperature sensor 28 is disposed to detect the temperature of the heat medium after the heat medium output from the shell side outlet 16d of the warming heat exchanger 16 and the heat medium from the bypass line 32 merge. Based on the value detected by the temperature sensor 28, the control valve 26 controls a flow rate of the heat medium flowing through the bypass line 32 such that the temperature of the heat medium after merging, that is, the temperature of the heat medium supplied to the heat medium drum 22, is equal to or higher than the freezing temperature (-2°C) of seawater.

[0031] The heat medium warmer 18 receives a supply of seawater (for example, 5°C or higher) and the heat medium (-2°C or higher) and warms the heat medium by heat exchange with the seawater. In the present embodiment, the heat medium warmer 18 is a plate-type heat exchanger provided with a titanium plate having excellent seawater corrosion resistance and abrasion resistance. The plate-type heat exchanger is characterized by having high heat transfer properties. In the plate-type heat exchanger, the fluids are substantially equilibrium amounts and have a high heat transfer coefficient, a deviation is small depending on location, and sufficient heat exchange is possible with a temperature difference of 2°C between the fluids. The seawater is input to a seawater inlet 18c of the heat medium warmer 18 by the seawater pump 20 and output from a seawater outlet 18d of the heat medium warmer 18. Meanwhile, the heat medium is input to a heat medium inlet 18a of the heat medium warmer 18 and output from a heat medium outlet 18b of the heat medium warmer 18.

[0032] The operation of the liquefied carbon dioxide warming equipment 10 will be described by exemplifying a specific temperature. Here, a case is considered in which a -20°C, 1.97 MPa liquefied carbon dioxide is pressurized and warmed to 0°C and 10 MPa. The heat medium warmer 18 receives a supply of, for example, 7°C seawater and a -1°C heat medium (ethylene glycol aqueous solution with a freezing temperature of -23°C) to warm the heat medium to 5°C. The heat medium warmed by the heat medium warmer 18 is supplied to the shell side inlet 16c of the warming heat exchanger 16 via the line 33. The booster pump 14 pressurizes the -20°C, 1.97 MPa liquefied carbon dioxide to -20°C and 10.5 MPa. The warming heat exchanger 16 warms the -20°C, 10.5 MPa liquefied carbon dioxide supplied to the tube side inlet 16a to 0°C (10.2 MPa) by heat exchange with the 5°C heat medium. When a -46°C, 0.80 MPa liquefied carbon dioxide is pressurized and warmed to 0°C and 10 MPa, an outlet of the booster pump 14 is -46°C and 10.5 MPa, and the temperature and pressure at the other portions are the same.

[0033] The configuration of the liquefied carbon dioxide warming equipment 10 according to the present embodiment has been described above. According to the liquefied carbon dioxide warming equipment 10 according to the present embodiment, since the liquefied carbon dioxide is warmed using seawater, costs can be reduced compared to a case in which a hot water boiler requiring fuel is used, and further, an extremely small amount of CO_2 is discharged.

[0034] A minimum temperature of seawater is 6°C to 8°C in winter on the Japan Sea side (4°C to 6°C in the northern sea). When the -10°C to -50°C liquefied carbon dioxide undergoes direct heat exchange with seawater at such a low temperature, the seawater may freeze in the heat exchanger, and the heat exchanger may be blocked. Therefore, by configuring heat exchange to be between the heat medium having a low freezing temperature and the liquefied carbon dioxide, such as in the liquefied carbon dioxide warming equipment 10 according to the present embodiment, blockages can be prevented in the heat exchanger.

[0035] In the heat medium warmer 18, heat is exchanged between the seawater and the heat medium. However, in the liquefied carbon dioxide warming equipment 10 according to the present embodiment, since the heat medium temperature controller 30 performs control so that the temperature of the heat medium input into the heat medium inlet 18a of the heat medium warmer 18 is equal to or higher than the freezing temperature of the seawater (about -2°C), freezing of the seawater does not occur in the heat medium warmer 18.

[0036] In the liquefied carbon dioxide warming equipment 10 according to the present embodiment, since the fluid supplied to the warming heat exchanger 16 has low corrosiveness, general steel can be used as a material instead of expensive titanium. As a result, the cost of the shell-and-tube warming heat exchanger 16 can be significantly reduced.

[0037] In the liquefied carbon dioxide warming equipment 10 according to the present embodiment, the heat medium warmer 18 is the plate-type heat exchanger provided with the titanium plate having excellent seawater corrosion resistance and abrasion resistance. While titanium is used due to its seawater corrosion resistance, since the thickness of the plate is as thin as 0.4 mm to 0.7 mm, the heat medium warmer 18 is inexpensive when compared to the shell-and-tube heat exchanger using titanium heat transfer tubes.

[0038] Fig. 3 is a view for describing liquefied carbon dioxide warming equipment 40 according to another embodiment of the present invention. The liquefied carbon dioxide warming equipment 40 shown in Fig. 3 differs from the liquefied carbon dioxide warming equipment 10 shown in Fig. 2 on the point of being further provided with a liquefied carbon dioxide vaporization heat exchanger 42.

[0039] The liquefied carbon dioxide vaporization heat exchanger 42 is a shell-and-tube heat exchanger, and the cylindrical shell and the heat transfer tubes are all made of general steel. One part of the heat medium from the heat medium outlet 18b of the heat medium warmer 18 is supplied to a tube side of the liquefied carbon dioxide vaporization heat exchanger 42. The heat medium is input to a tube side inlet 42a of the liquefied carbon dioxide vaporization heat exchanger 42, then output from a tube side outlet 42b and merged with the heat medium from the warming heat exchanger 16 by the line 34. Meanwhile, one part of the liquefied carbon dioxide from the storage tank 12 is supplied to a shell side of the liquefied carbon dioxide vaporization heat exchanger 42. The liquefied carbon dioxide is input to a shell side inlet 42c of the liquefied carbon dioxide vaporization heat exchanger 42, vaporized by heat exchange with the heat medium, then output from a shell side outlet 42d. The carbon dioxide output from the shell side outlet 42d of the liquefied carbon dioxide vaporization heat exchanger 42 is supplied to the storage tank 12 as a return gas.

[0040] In the liquefied carbon dioxide warming equipment 40 according to the present embodiment, by vaporizing one part of the liquefied carbon dioxide and supplying it as a return gas to the storage tank 12, the pressure of the storage tank 12 due to the delivery of the liquefied carbon dioxide can be prevented from decreasing.

[0041] The operation of the liquefied carbon dioxide warming equipment 40 will be described by exemplifying a specific temperature. Here, a case is considered in which a -20°C, 1.97 MPa liquefied carbon dioxide is pressurized and warmed to 0°C and 10 MPa. The heat medium warmer 18 receives a supply of, for example, 7°C seawater and a -1°C heat medium (ethylene glycol aqueous solution with a freezing temperature of -23°C) to warm the heat medium to 5°C. The heat medium warmed by the heat medium warmer 18 is supplied to the shell side inlet 16c of the warming heat exchanger 16 via the line 33. The booster pump 14 pressurizes the -20°C, 1.97 MPa liquefied carbon dioxide to -20°C and 10.5 MPa. The warming heat exchanger 16 warms the -20°C, 10.5 MPa liquefied carbon dioxide supplied to the tube side inlet 16a to 0°C (10.2 MPa) by heat exchange with the 5°C heat medium. One part of the - 20°C, 1.97 MPa liquefied carbon dioxide is supplied to the shell side inlet 42c of the liquefied carbon dioxide vaporization heat exchanger 42. The liquefied carbon dioxide vaporization heat exchanger 42 vaporizes the liquefied carbon dioxide supplied to the shell side inlet 42c by heat exchange with the 5°C heat medium supplied to the tube side inlet 42a and outputs the liquefied carbon dioxide from the shell side outlet 42d (-20°C, 1.97 MPa). When the -46°C, 0.80 MPa liquefied carbon dioxide is pressurized and warmed to 0°C and 10 MPa, the outlet of the booster pump 14 is -46°C and 10.5 MPa, the shell side outlet 42d of the liquefied carbon dioxide vaporization heat exchanger 42 is -46°C and 0.80 MPa, and the temperature and pressure at the other portions are the same.

[0042] The present invention has been described above based on the embodiments. It should be understood by those skilled in the art that the embodiments are examples; various examples of modification to the combination of each constituent element and each treatment process are possible, and such modification examples are also within the scope of the present invention.

INDUSTRIAL APPLICABILITY

[0043] The present invention can be used in carbon capture and storage (CCS).

REFERENCE SIGNS LIST

[0044] 10, 40 liquefied carbon dioxide warming equipment, 12 storage tank, 14 booster pump, 16 warming heat exchanger, 18 heat medium warmer, 20 seawater pump, 22 heat medium drum, 26 control valve, 28 temperature sensor, 30 heat medium temperature controller, 32 bypass line, 42 liquefied carbon dioxide vaporization heat exchanger, 100 liquefied CO_2 transport ship

Claims

1. Liquefied carbon dioxide warming equipment comprising:

a heat medium warmer that receives a supply of seawater and a heat medium and warms the heat medium by heat exchange with the seawater;
a warming heat exchanger that warms liquefied carbon dioxide to a predetermined temperature by heat exchange with the heat medium warmed by the heat medium warmer; and
a heat medium temperature controller that performs control such that a temperature of the heat medium supplied to the heat medium warmer is equal to or higher than a freezing temperature of the seawater.

2. The liquefied carbon dioxide warming equipment according to claim 1, wherein

the warming heat exchanger is a shell-and-tube heat exchanger in which a plurality of heat transfer tubes are housed in a cylindrical shell,
the liquefied carbon dioxide is supplied to a side of the heat transfer tubes of the warming heat exchanger, and
the heat medium from the heat medium warmer is supplied to a side of the cylindrical shell of the warming heat exchanger.

3. The liquefied carbon dioxide warming equipment according to claim 2, wherein the cylindrical shell and the heat transfer tubes of the warming heat exchanger are all made of steel.

4. The liquefied carbon dioxide warming equipment according to any one of claims 1 to 3, wherein the heat medium is an ethylene glycol aqueous solution, a propylene glycol aqueous solution, a mixed solution of the ethylene glycol aqueous solution and the propylene glycol aqueous solution, or a solution of a hydrocarbon compound.

5. The liquefied carbon dioxide warming equipment according to any one of claims 1 to 4, wherein the heat medium warmer is a plate-type heat exchanger provided with a titanium plate.

6. The liquefied carbon dioxide warming equipment according to any one of claims 1 to 5, further comprising:

a storage tank that stores the liquefied carbon dioxide to be supplied to the warming heat exchanger; and
a liquefied carbon dioxide vaporization heat exchanger that receives a supply of one part of the liquefied carbon dioxide from the storage tank and one part of the heat medium from the heat medium warmer and vaporizes the liquefied carbon dioxide by heat exchange with the heat medium,
wherein the carbon dioxide vaporized by the liquefied carbon dioxide vaporization heat exchanger is supplied to the storage tank.

7. A method of liquefied carbon dioxide warming comprising:

supplying seawater and a heat medium to a heat medium warmer;
warming the heat medium by heat exchange with the seawater using the heat medium warmer;
warming the liquefied carbon dioxide to a predetermined temperature by heat exchange with the heat medium; and
performing control so that a temperature of the heat medium supplied to the heat medium warmer is equal to or higher than a freezing temperature of the seawater.

FIG. 1

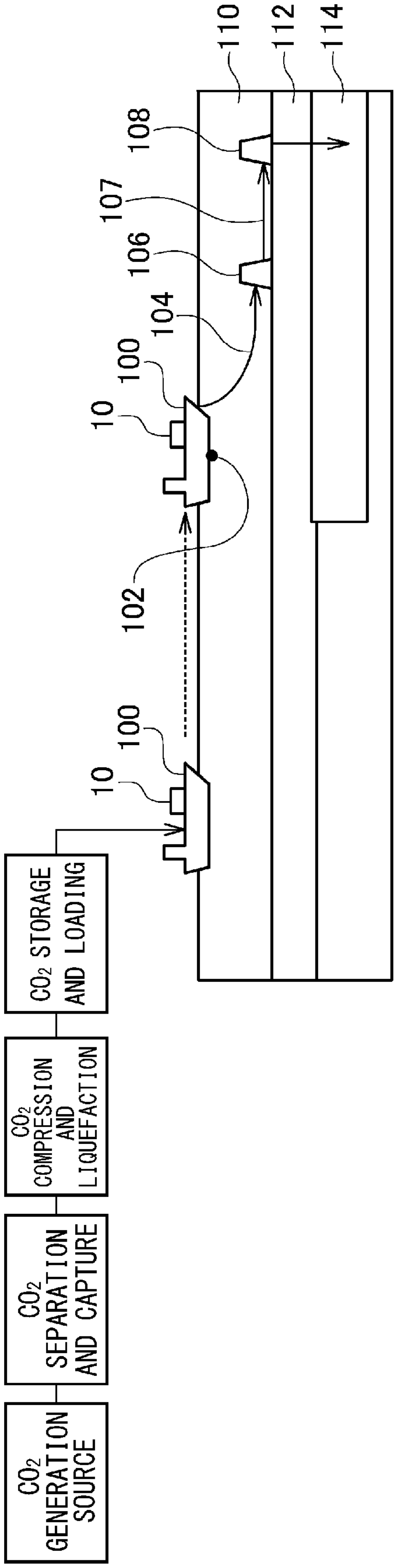

CO2 GENERATION SOURCE
CO2 SEPARATION AND CAPTURE
CO2 COMPRESSION AND LIQUEFACTION
CO2 STORAGE AND LOADING
10
100
10
100
102
104
106
107
108
110
112
114

FIG. 2

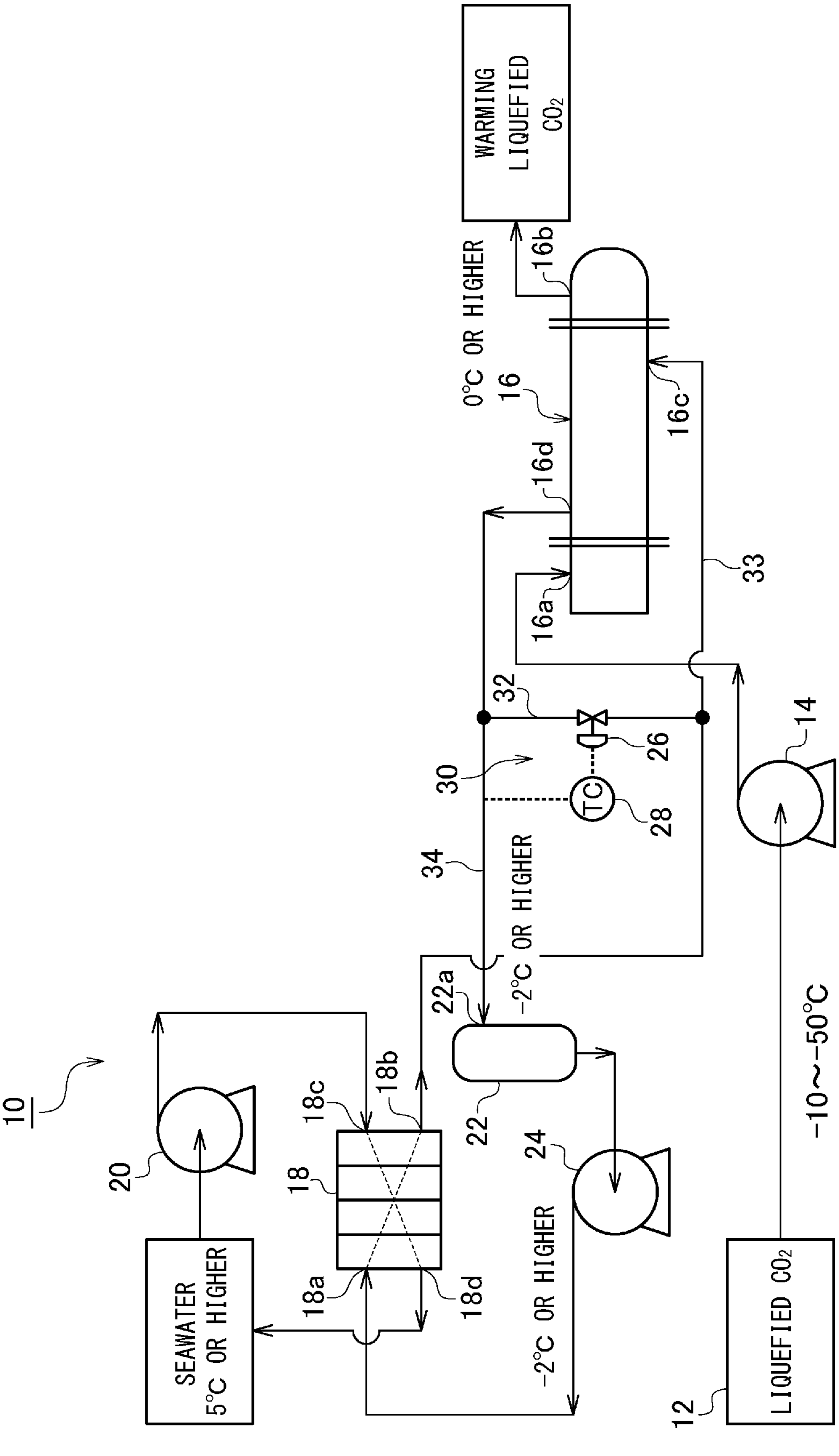
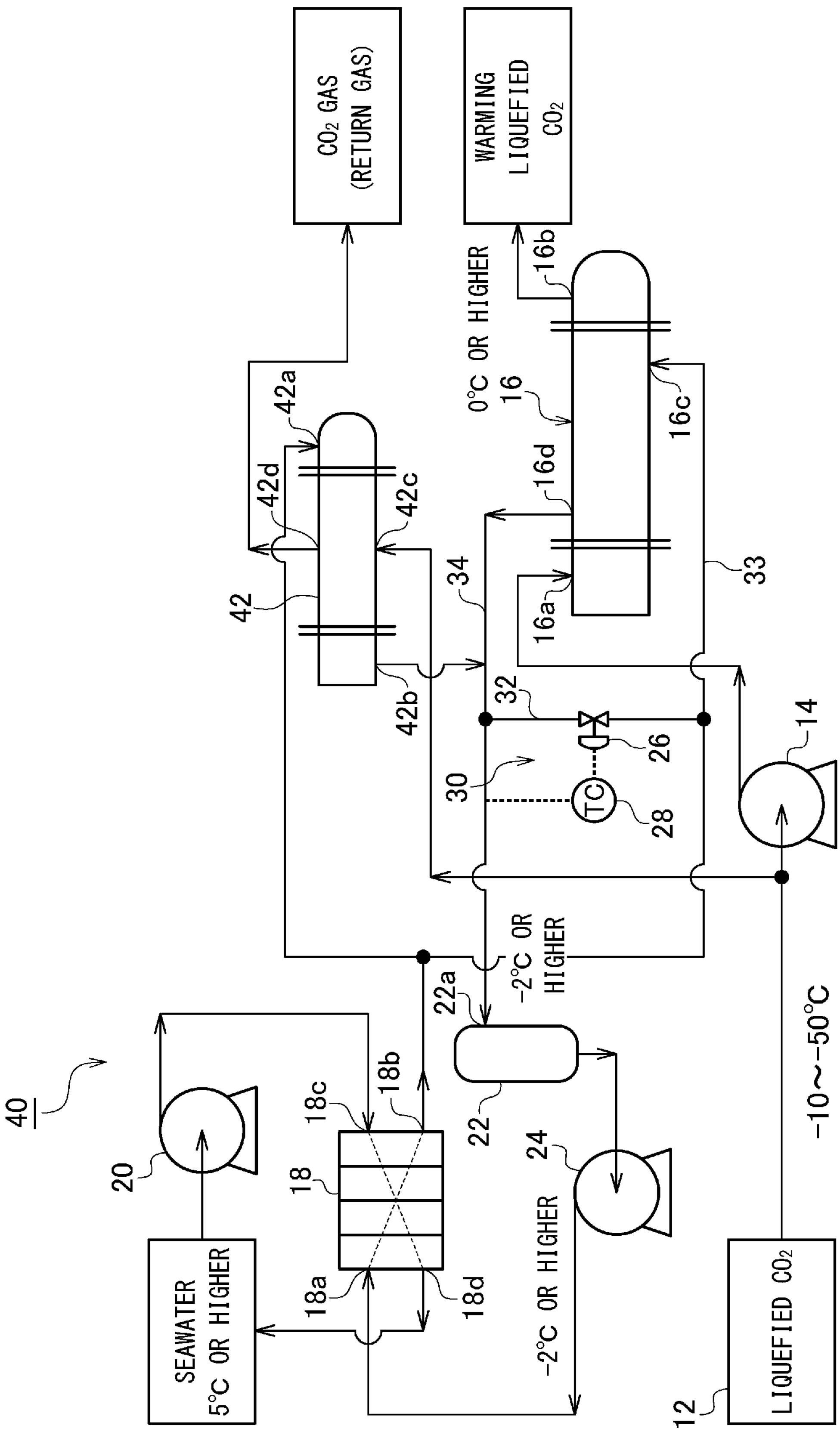

WARMING LIQUEFIED CO2
0°C OR HIGHER
16b
16
16d
16c
16a
33
32
30
26
TC
28
34
14
−2°C OR HIGHER
22a
22
24
10
20
18c
18b
18
18a
18d
SEAWATER 5°C OR HIGHER
−2°C OR HIGHER
−10～−50°C
LIQUEFIED CO2
12

FIG. 3


40
SEAWATER
5°C OR HIGHER
20
18
18a
18b
18c
18d
22
22a
24
-2°C OR HIGHER
-2°C OR HIGHER
LIQUEFIED CO2
12
-10～-50°C
14
TC
26
28
30
32
33
34
16
16a
16b
16c
16d
0°C OR HIGHER
WARMING
LIQUEFIED
CO2
CO2 GAS
(RETURN GAS)
42
42a
42b
42c
42d

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2022/023260

A. CLASSIFICATION OF SUBJECT MATTER

B63B 25/16(2006.01)i; ***F17C 7/02***(2006.01)i; ***B01J 19/00***(2006.01)i
FI: B01J19/00 301A; B63B25/16 Z; F17C7/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B01J19/00; B63B25/00-16, 35/00, 44; F17C7/00-04, 13/00; C01B32/50

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2022
Registered utility model specifications of Japan 1996-2022
Published registered utility model applications of Japan 1994-2022

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2009-78228 A (NATIONAL MARITIME RESEARCH INST.) 16 April 2009 (2009-04-16) claims, paragraphs [0014]-[0036], fig. 1, 3	1, 7
Y	claims, paragraphs [0014]-[0036], fig. 1, 3	2-5
Y	JP 49-17549 A (MITSUI ENGINEERING & SHIPBUILDING CO., LTD.) 16 February 1974 (1974-02-16) page 1, lower right column, line 4 to page 3, upper right column, line 1, fig. 1-8	2-5
Y	JP 2002-340296 A (SUMITOMO PRECISION PROD. CO., LTD.) 27 November 2002 (2002-11-27) paragraphs [0009], [0016]-[0023], examples	2-5
Y	JP 63-41795 A (KOBE STEEL, LTD.) 23 February 1988 (1988-02-23) page 1, lower left column, line 2 from the bottom to page 2, upper right column, line 8	5
A	JP 7-241459 A (MITSUBISHI HEAVY IND., LTD.) 19 September 1995 (1995-09-19)	1-7
A	JP 2017-120125 A (KOBE STEEL, LTD.) 06 July 2017 (2017-07-06)	1-7
A	JP 2009-185959 A (SHOWA TANSAN CO., LTD.) 20 August 2009 (2009-08-20)	1-7

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
02 August 2022	**16 August 2022**
Name and mailing address of the ISA/JP **Japan Patent Office (ISA/JP)** **3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915** **Japan**	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

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