(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 4 467 471 A1

(12) # EUROPEAN PATENT APPLICATION

published in accordance with Art. 153(4) EPC

(43) Date of publication:
27.11.2024 Bulletin 2024/48

(21) Application number: **23742868.5**

(22) Date of filing: **17.01.2023**

(51) International Patent Classification (IPC):
B65B 25/12 *(2006.01)* ***B63B 35/44*** *(2006.01)*
B63B 27/34 *(2006.01)*

(52) Cooperative Patent Classification (CPC):
B63B 27/34; B63B 35/00; B63B 35/44; B65B 25/12; F17C 1/12; F17C 3/04; F17C 5/02; F17C 6/00; F17C 7/02; F17C 9/00; F17C 13/00; F17C 13/02; F17C 13/04

(86) International application number:
PCT/CN2023/072515

(87) International publication number:
WO 2023/138553 (27.07.2023 Gazette 2023/30)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA
Designated Validation States:
KH MA MD TN

(30) Priority: **18.01.2022 CN 202210055953**

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(54) **NOVEL CO2 MARITIME TRANSSHIPMENT AND STORAGE SYSTEM**

(57) A COz maritime transshipment and storage system, consisting of five parts, namely CO_2 transmission, CO_2 loading and unloading, CO_2 transportation, CO_2 injection, and CO_2 storage. When dock loading conditions are satisfied, a CO_2 land storage terminal (3) conveys to a CO_2 filling apparatus by means of a land pipeline (5), a CO_2 transportation ship is filled, and after a destination is reached, dock unloading is performed by means of a CO_2 transshipment system (22), and transmission to a CO_2 injection module (23) is performed by means of a pipeline, for injection to a land or seabed CO_2 storage site for storage. When dock loading conditions are not satisfied, the CO_2 land storage terminal (3) conveys to a CO_2 maritime floating storage apparatus by means of a pipeline, the CO_2 transportation ship moors with said apparatus in an adjacent or side-by-side mode,

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CO_2 filling is completed by means of soft pipe transmission, and after the CO_2 transportation ship reaches a target sea area, transmission to a CO_2 maritime injection platform is performed by means of an internal turret apparatus, a seabed pipeline (6) and an underwater vertical pipe (13), for injection by means of a seabed wellhead (26) to a seabed CO_2 storage site (25) for storage.

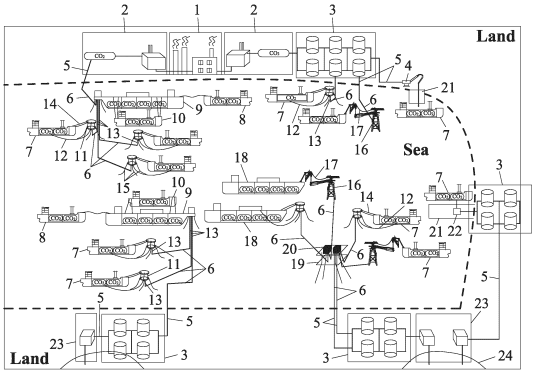

FIG. 1

Description

[0001] The disclosure relates to the field of carbon capture, transportation, and storage (CCUS), and more specifically, to a novel CO_2 maritime transshipment and storage system for the separation of CO_2 from sources such as industrial processes, energy utilization, or the atmosphere. The separated CO_2 is then transported and stored in geological formations, on land or under the sea, with the objective of achieving permanent reduction of CO_2 levels in the atmosphere.

[0002] Under the objective of achieving carbon neutrality, the aggressive advantage of the CCUS technology represents a strategic decision for China to significantly reduce carbon dioxide (CO_2) emissions while safeguarding future energy security. The CCUS technology is also pivotal for fostering ecological civilization and facilitating sustainable development. Unlike the development of new alternative energy sources, CCUS technology effectively reduces greenhouse gas emissions in the short term. Developing CCUS technology helps to balance the ongoing reliance on fossil fuels with the implementation of carbon reduction policies. Additionally, CCUS is a key technical method for maintaining the flexibility of power systems within the framework of carbon neutrality. Moreover, the CCUS technology offers viable pathways for achieving zero emissions in energy-intensive industries, thereby enhancing China's influence in the international low-carbon discourse.

[0003] China has prioritized the development of CCUS technology, making significant strides in onshore research and application. However, compared to other countries, China initiated research on marine CO_2 storage later than other countries, leaving areas such as CO_2 ocean transportation and seabed storage largely unexplored. Marine carbon sequestration offers potential advantages over onshore methods, including being located far from residential areas, which enhances its reliability and environmental compatibility. China's main carbon emission sources are concentrated in coastal areas, where nearby coastal basins offer favourable conditions for carbon sequestration. Additionally, China possesses robust design and manufacturing capabilities in the marine and shipbuilding sectors, providing favourable conditions for the implement of ocean CCUS. Although the cost of marine carbon sequestration is slightly higher than that of onshore alternatives, the flexibility afforded by maritime transportation allows for the serving of a broader range of carbon sources. Furthermore, as domestic carbon tax policies and carbon trading markets evolve, the economic feasibility of ocean CCUS is expected to improve.

[0004] To solve the aforesaid problems, the first objective of the disclosure is to provide a novel CO_2 maritime transshipment and storage system to enhance the efficiency of CO_2 transportation. The novel CO_2 maritime transshipment and storage system facilitate the effective CO_2 storage and supports the growth of the carbon trading market, thereby creating significant economic value.

[0005] The novel CO_2 maritime transshipment and storage system comprises a CO_2 transmission part, a CO_2 loading and unloading part, a CO_2 transportation part, a CO_2 injection part, and a CO_2 storage part.

[0006] In a class of this embodiment, when loading conditions are satisfied, liquid CO_2 is transported from an onshore CO_2 storage terminal to a CO_2 loading device through an onshore pipeline; the CO_2 is then transferred to a CO2 transport ship; when the CO_2 transport ship reaches a designated sea area, the liquid CO_2 is offloaded via a CO_2 transfer system, conveyed to a CO_2 injection module through the onshore pipeline, and then is injected into an onshore CO_2 storage site or a submarine CO_2 storage site.

[0007] In a class of this embodiment, when the loading conditions are not satisfied, the liquid CO_2 is transported from the onshore CO_2 storage terminal to a floating CO_2 storage device through a subsea pipeline; the CO_2 transport ship is moored in an inline or side-by-side configuration with the floating CO_2 storage device; the CO_2 is offloaded from the CO_2 transport ship to the floating CO_2 storage device via a hose; upon reaching the designated sea area, the CO_2 transport ship is moored in an inline or side-by-side configuration with the floating CO_2 storage device; the floating CO_2 storage device comprises a plurality of internal turrets; the CO_2 is transferred from the CO_2 transport ship to the floating CO_2 storage device through the hose; subsequently, the CO_2 is transmitted to an offshore CO_2 injection platform through the plurality of internal turrets, a subsea pipeline, and an underwater riser; finally, the CO_2 is injected into a submarine CO_2 storage site through a submarine wellhead, ensuring long-term storage.

[0008] When the loading conditions are not satisfied, the CO_2 is transmitted from the onshore CO_2 storage terminal to the floating CO_2 storage device through the subsea pipeline; after the floating CO_2 storage device arrives at the designated sea area, the CO_2 is conveyed to the offshore CO_2 injection platform through the plurality of internal turrets, the subsea pipeline, and the underwater riser; finally, the CO_2 is injected into the submarine CO_2 storage site through a submarine wellhead, ensuring long-term storage.

[0009] The onshore pipeline, the subsea pipeline, the underwater riser, and the hose are a set of pipelines having thermal insulation and pressure-assistant properties. The CO_2 transmitted through the set of pipelines is in gaseous, liquid, or supercritical state.

[0010] When the CO_2 is in a liquid state, the pressure within the set of pipelines ranges from 0.4 MPa to 7.39 MPa. When the CO_2 is in a supercritical state, the CO_2 in the set of pipelines is maintained at temperatures above 31.3°C, with the pressure exceeding 7.39 MPa. When the CO_2 is in a gaseous state, the pressure within the set of pipelines ranges from 0 to 7.39 MPa.

[0011] The CO_2 transport ship comprises a C-type tank for storage; the CO_2 transport ship is used to contain the CO_2 at pressures ranging from 0.4 MPa to 2.1 MPa.

[0012] The novel CO_2 maritime transshipment and storage system is applicable to the maritime transshipment and storage of CO_2 under various conditions. The novel CO_2 maritime transshipment and storage system optimized the efficiency of CO_2 transportation. The optimization establishes a foundation for CO_2 storage operations and facilitates the growth of the carbon trading market, thereby creating significant economic value.

[0013] The second objective of the disclosure is to provide a deep-sea storage method that is cost-effective, efficient, and allows for repeated use of a liquid CO_2 tank. The deep-sea storage method comprises:

S1. injecting liquid CO_2 into a liquid CO_2 tank; where, the liquid CO_2 tank comprises a tank body used to store the liquid CO_2; the tank body comprises a thermal insulation layer; the liquid CO_2 tank further comprises a discharge tank and an injection device; the discharge tank and the injection device are disposed on a first end and a second end of the tank body, respectively; the injection device comprises a unidirectional valve; the center of gravity of the tank body is tilted towards the first end of the tank body; the liquid CO_2 tank further comprises a nitrogen generation device disposed inside the tank body, specifically disposed at the second end of the tank body; the discharge device comprises a pressure-controlled relief device; and the liquid CO_2 tank further comprises a pressure-controlled valve;

S2. transporting, by a ship, the liquid CO_2 tank to an ocean storage area;

S3. releasing the liquid CO_2 tank into the seawater; where, the center of gravity of the tank body is tilted towards the first end of the tank body; the liquid CO_2 tank sinks in a vertical position, with the first end of the tank body facing downward;

S4. opening the pressure-controlled relief device to release the internal pressure when the internal pressure reaches the activation pressure of the pressure-controlled relief device;

S5. opening the injection device to permit the seawater to flow into the liquid CO_2 tank when the external seawater pressure reaches the activation pressure of the injection device;

S6. fully opening both the injection device and the discharge device when the liquid CO_2 tank reaches a designated CO_2 storage depth, and closing the injection device when the liquid CO_2 tank is filled with the seawater; where, the injection device and the discharge device are actuated to an open state, permitting the release of the liquid CO_2 from the liquid CO_2 tank;

S7. activating the nitrogen generation device to produce nitrogen gas, and closing the discharge device to seal the liquid CO_2 tank after the seawater exit the liquid CO_2 tank; where, the nitrogen gas displaces the seawater from the liquid CO_2 tank, making the liquid CO_2 tank buoyant and causing the liquid CO_2 tank to float on the surface of the sea; and

S8. retrieving the liquid CO_2 tank floating on the surface of the sea due to buoyancy.

[0014] In a class of this embodiment, the liquid CO_2 tank achieves a center of gravity that is biased towards the first end of the tank body by attaching a fixed weight.

[0015] In a class of this embodiment, the liquid CO_2 tank further comprises a satellite positioning device used to locate the liquid CO_2 tank when the liquid CO_2 tank floats to the surface of the sea due to buoyancy.

[0016] In a class of this embodiment, the liquid CO_2 tank further comprises a position monitoring device used to determine the depth at which the liquid CO_2 tank has sunk; each of the injection device and the discharge device has a remote control mechanism; the remote control mechanisms allow the injection device and the discharge device to operate respectively when the liquid CO_2 tank sinks to a target depth as detected by the position monitoring device.

[0017] In a class of this embodiment, the liquid CO_2 tank has a maximum allowable pressure of 30 bar, and in S6, a minimum depth for CO_2 storage is 1000 meters underwater.

[0018] The disclosure addresses the challenge of safely transporting and storing CO_2 in deep-sea environments while keeping costs low. Specifically, the disclosure provides the liquid CO_2 tank that is capable of being repeatedly recovered and reused after releasing the liquid CO_2. The liquid CO_2 tank uses pressure control to automatically discharge the liquid CO_2 at the target depth. Compared to the related art, the pressure control technology makes the operation safer and more reliable by minimizing the need for manual control. Additionally, the liquid CO_2 tank is able to suspend in the seawater, releasing the liquid CO_2 while floating rather than resting on the seabed. The suspend design allows the liquid CO_2 tank to be reused for further operations.

FIG. 1 is a schematic diagram of a general layout of CO_2 onshore storage according to one example of the disclosure;

FIG. 2 is a schematic diagram of a general layout of CO_2 seabed storage according to one example of the disclosure;

FIG. 3 is a flowchart of a first part of a novel CO_2 maritime transshipment and storage system according to one example of the disclosure;

FIG. 4 is a flowchart of a second part of a novel CO_2 maritime transshipment and storage system according to one example of the disclosure;

FIG. 5 is a flowchart of a third part of a novel CO_2 maritime transshipment and storage system according to one example of the disclosure;

FIG. 6 is a flowchart of a fourth part of a novel CO_2 maritime transshipment and storage system according to one example of the disclosure;

FIG. 7 is a schematic diagram of a liquid CO_2 tank according to one example of the disclosure;

FIG. 8 is a schematic diagram of a part of a discharge device shown in FIG. 7;

FIG. 9 is a schematic diagram of a state of a liquid CO_2 tank transported by a ship according to one example of the disclosure;

FIG. 10 is a process of achieving CO_2 storage in a target sea area;

FIG. 11 is a schematic diagram showing a state after a liquid CO_2 tank has released liquid CO_2 according to one example of the disclosure;

FIG. 12 is a schematic diagram showing a process of the liquid CO_2 tank returning;

FIG. 13 is a schematic diagram showing a state of the liquid CO_2 tank being recovered;

FIG. 14 is a schematic diagram showing a state of a ship completing the recovery of the liquid CO_2 tank.

[0019] In the drawings, the following reference numbers are used:
1. Industrial activities; 2. CO_2 capture module; 3. Onshore CO_2 storage terminal; 4. Onshore CO_2 loading arm; 5. Onshore CO_2 transmission pipeline; 6. Subsea CO_2 transmission pipeline; 7. First CO_2 transport ship; 8. Second CO_2 transport ship; 9. First floating CO_2 storage device; 10. Third CO_2 transport ships; 11. Catenary anchor leg mooring device; 12. Floating hose; 13. Underwater riser; 14. Mooring line; 15. Mooring anchor chain; 16. Soft-rigid arm anchor leg mooring device; 17. Transmission hose; 18. Second floating CO_2 storage device; 19. Jacket-type CO_2 pressurized transmission platform; 20.COz booster transmission module; 21.COz loading and unloading dock; 22.CO_2 transfer system; 23.First CO_2 injection module; 24.Onshore CO_2 storage site. 25. Submarine CO_2 storage site; 26. Submarine wellhead; 27. Conduit-type CO_2 injection platform; 28.Second CO_2 injection module; 91.Injection device; 92.Discharge device; 93.Satellite positioning device; 94.Nitrogen generation device; 95.Tank body; 96. Pressure-controlled relief device; and 97.Gas escape device.

[0020] FIG. 1 is a schematic diagram of a general layout of CO_2 onshore storage. In the process of managing CO_2 emissions from industrial activities, CO_2 produced 1 is collected by a CO_2 capture module 2 and then stored in liquid form at an onshore CO_2 storage terminal 3. The liquid CO_2 is transported over a long distance to a submarine wellhead for storage. Specifically, when a CO_2 transport ship is docked, the liquid CO_2 is transported to an onshore CO_2 loading arm 4 via an onshore CO_2 transportation pipeline 5 and then is offloaded to a first CO_2 transport ship 7. Alternatively, the liquid CO_2 is transferred to a catenary anchor leg mooring device 11 via a subsea CO_2 transmission pipeline 6 and an underwater riser 13, and then is offloaded to the first CO_2 transport ship 7 through a floating hose 12. Alternatively, the liquid CO_2 is transferred to a soft-rigid arm anchor leg mooring device 16 through the subsea CO_2 transport pipeline 6 and the underwater riser 13, and then offloaded to the first CO_2 transport ship 7 through a transmission hose 17.

[0021] A first floating CO_2 storage device 9 comprises a plurality of internal turrets disposed in the nearshore waters to improve the efficiency of CO_2 storage and transmission. The CO_2 from the industrial activities 1 is collected by the CO_2 capture module 2, and then transmitted in liquid form through the subsea CO_2 transmission pipeline 6 to the first floating CO_2 storage device 9. The first floating CO_2 storage device 9 is used to transfer the CO_2 to a second mooring CO_2 transport ship 8 and a third CO_2 transport ship 10. The term "The second CO_2 transport ship", as used herein, refers to a CO_2 transport ship that is moored in an inline configuration with the first floating CO_2 storage device 9 or a second floating CO_2 storage device 18. The term "third CO_2 transport ship", as used herein, refers to a CO_2 transport ship that is moored in a side-by-side configuration with the first floating CO_2 storage device 9 or a second floating CO_2 storage device 18. Alternatively, to improve the efficiency of CO_2 loading and unloading, a plurality of catenary anchor leg mooring devices 11 are employed and fixed to the seabed with mooring anchor chains 15. The CO_2 is transferred from the first floating CO_2 storage device 9 to the catenary anchor leg mooring device 11 through the subsea CO_2 transmission pipelines 6 and the underwater riser 13. The first CO2 transport ship 7 is moored and connected to the catenary anchor leg mooring device 11 via a mooring line 14. The liquid CO_2 is transferred from the catenary anchor leg mooring device 11 to first CO_2 transport ship 7 through the floating hose 12. Alternatively, the CO_2 from the industrial activities 1 is collected by the CO_2 capture module 2 and then transmitted in liquid form through the subsea CO_2 transmission pipeline 6 to the second floating CO_2 storage device 18.

[0022] When the first CO_2 transport ship 7 reaches a designated sea area and unloading conditions are satisfied, the first CO_2 transport ship 7 berths at a CO_2 loading and unloading dock 21. The CO_2 is transferred through a CO_2 transfer system 22 to the onshore CO_2 storage terminal 3. The CO_2 is then conveyed through the onshore CO_2 transmission pipelines 5 to a first CO_2 injection module 23 and subsequently is injected into an onshore CO_2 storage site 24.

[0023] When the first floating CO_2 storage device 9 loaded with the CO_2 reaches the designated sea area, if the unloading conditions are not satisfied, the CO_2 is transferred to the onshore CO_2 storage terminal 3 through the underwater riser 13, the subsea CO_2 transmission pipeline 6, and the onshore CO_2 transmission pipeline 5 over long distances. Notably, the subsea CO_2 transmission pipeline 6 is pre-laid on the seabed. The CO_2 is then transferred through the onshore CO_2 transmission pipelines 5 to the first CO_2 injection module 23 and subsequently injected into the onshore CO_2 storage site 24. Alternatively, the long-distance CO_2 transmission is achieved through a jacket-type CO_2 pressurized transmission platform 19. Specifically, the first CO_2 transport ship 7 and the second floating CO_2 storage device 18 are separately moored and connected to the catenary anchor leg mooring device 11 via the mooring line 14. The CO_2 is transmitted to the catenary anchor leg mooring device 11 through the floating hose 12. Alternatively, the first CO_2 transport ship 7 and the second floating CO_2 storage device 18 are separately moored and connected to the soft-rigid arm anchor leg mooring device 16 through the transmission hose 17. The CO_2 is transmitted to the soft-rigid arm anchor leg mooring device 16 through the transmission hose 17. Subsequently, the CO_2 is transported from the catenary anchor leg mooring device 11 or the soft-rigid arm anchor leg mooring device 16 to the jacket-type CO_2 pressurized transmission platform 19 through the subsea CO_2 transmission pipeline 6 and the underwater riser 13. The CO_2 is pressurized by a CO_2 booster transmission module 20 and transmitted through the subsea CO_2 transmission pipeline 6 and the onshore CO_2 transmission pipeline 5 to the first CO_2 injection module 23 and subsequently is injected into the onshore CO_2 storage site 24.

[0024] To improve the unloading efficiency, the plurality of catenary anchor leg moorings devices 11 are employed. The first floating CO_2 storage device 9 is used as a transfer station for CO_2. Specifically, the CO_2 is transmitted from the second CO_2 transport ship 8 and the third CO_2 transport ship 10 to the first floating CO_2 storage device 9. Additionally, the first CO_2 transport ship 7 is moored and connected to catenary anchor leg mooring device 11 through the mooring line 14. The CO_2 is transmitted to the catenary anchor leg mooring device 11 via the floating hose 12 and subsequently is conveyed to the first floating CO_2 storage device 9 through the subsea CO_2 transmission pipeline 6 and the underwater riser 13. The CO_2 is transferred from the first floating CO_2 storage device 9 to the onshore CO_2 storage terminal 3 through the subsea CO_2 transmission pipeline 6, the underwater riser 13, and the onshore CO_2 transmission pipelines 5, transferred through the onshore CO_2 transmission pipeline 5 to the first CO_2 injection module 23, and injected into the onshore CO_2 storage site 24.

[0025] Many abandoned oil fields are suited offshore, in the sea. FIG. 2 is a schematic diagram showing a general layout of CO_2 undersea storage. As shown in FIG. 2, the CO_2 from industrial activities is collected by the CO_2 capture module 2 and stored in liquid form at the onshore CO_2 storage terminal 3. The CO_2 is then transported over a long distance to a submarine wellhead 26 for storage. The liquid CO_2 is transmitted to the onshore CO_2 loading arm 4 through the onshore CO_2 transmission pipeline 5 and then is offloaded to the first CO_2 transport ship 7. Alternatively, the CO_2 is transferred to the catenary anchor leg mooring device 11 via the subsea CO_2 transmission pipeline 6 and the underwater riser 13, and then is offloaded to the first CO_2 transport ship 7 through the floating hose 12. Alternatively, the CO_2 is transferred to the soft-rigid arm anchor leg mooring device 16 through the subsea CO_2 transmission pipeline 6 and the underwater riser 13, and then is offloaded to the first CO_2 transport ship 7 through the transmission hose 17. When the first CO_2 transport ship 7 arrives at the designated sea area and unloading conditions are satisfied, the first CO_2 transport ship 7 berths at a CO_2 loading and unloading dock 21. The CO_2 is transferred through a CO_2 transfer system 22 to the onshore CO_2 storage terminal 3. The subsea CO_2 transmission pipeline 6 is connected to the submarine wellhead 26. The CO_2 is conveyed to the first CO_2 injection module 23 and subsequently transmitted to the submarine CO_2 storage site 25 through the subsea CO_2 transmission pipeline 6 and the submarine wellhead 26.

[0026] To improve the storage and transmission efficiency of CO_2, the first floating CO_2 storage device 9 is disposed in the nearshore sea areas. CO_2 produced from industrial activities 1 is collected by a CO_2 capture module 2. The collected CO_2 is converted into liquid form and transmitted to the first floating CO_2 storage device 9 through the subsea CO_2 transmission pipeline 6, and then transmitted to the second CO_2 transport ship 8 and the third CO_2 transport ship 10. Alternatively, to improve the loading and unloading efficiency of CO_2, the plurality of catenary anchor leg mooring devices 11 are employed. The catenary anchor leg mooring device 11 is employed and fixed to the seabed via the mooring anchor chain 15. The CO_2 is transferred from the first floating CO_2 storage device 9 to the catenary anchor leg mooring device 11 through the subsea CO_2 transmission pipeline 6 and the underwater riser 13. The first CO_2 transport ship 7 is moored and connected to the catenary anchor leg mooring device 11 via the mooring line 14. The CO_2 is transferred from the catenary anchor leg mooring device 11 to the first CO_2 transport ship 7 via the floating hose 12. Alternatively, the CO_2 from the industrial activities 1 is collected by the CO_2 capture module 2 and converted into liquid form; the liquid CO_2 is transferred through the subsea CO_2 transmission pipeline 6 to the second floating CO_2 storage device 18.

[0027] When the first floating CO_2 storage device 9 loaded with the CO_2 arrives at the designated sea area, the CO_2 is transmitted to a second CO_2 injection module 28 disposed on a conduit-type CO_2 injection platform 27 through the underwater riser 13 and the subsea CO_2 transmission pipeline 6. Subsequently, the CO_2 is injected into the submarine CO_2 storage site 25 through the underwater riser 13 and the submarine wellhead 26.

[0028] The CO_2 is transferred from the second CO_2 transport ship 8 and the third CO_2 transport ships 10 to the first floating CO_2 storage device 9. Additionally, the first CO2 transport ship 7 is moored and connected to the catenary anchor leg mooring device 11 via the mooring line 14. The CO_2 is transferred to the catenary anchor leg mooring device 11 through the floating hose 12, and subsequently is transferred to the first floating CO_2 storage device 9 through the subsea pipeline 6 and the underwater riser 13. The CO_2 is transferred to the second CO_2 injection module 28 disposed on the conduit-type CO_2 injection platform through the underwater riser 13 and the subsea CO_2 transmission pipeline 6. Finally, the CO_2 is injected into the submarine CO_2 storage site 25 through the underwater riser 13 and the submarine wellhead 26.

[0029] The second CO_2 transport ships 8 and the third CO_2 transport ship 10 are separately moored and connected to the second floating CO_2 storage device 18. The second floating CO_2 storage device 18 is moored and connected to the catenary anchor leg mooring device 11 via the mooring line 14. The CO_2 is transmitted to the catenary anchor leg mooring devices 11 through the floating hose 12. Alternatively, the second floating CO_2 storage device 18 is moored and connected to the soft-rigid arm anchor leg mooring device 16 via the transmission hose 17, so that the CO_2 is transmitted from the second floating CO_2 storage device 18 to the soft-rigid arm anchor leg mooring device 16 through the transmission hose 17. The CO_2 is transmitted from the catenary anchor leg mooring device 11 or the soft-rigid arm anchor leg mooring device 16 to the second CO_2 injection module 28 disposed on the conduit-type CO_2 injection platform 27 through the underwater riser 13 and the subsea CO_2 transmission pipeline 6. The underwater riser 13 is connected to the submarine wellhead 26, so that the CO_2 is then injected into the submarine CO_2 storage site 25 through the underwater riser 13 and the submarine wellhead 26.

[0030] As shown in FIGS. 7-9, the disclosure provides a liquid CO_2 tank that is capable of self-recovered, self-regulating pressure release, and maintaining a suspended state. The liquid CO_2 tank comprises a tank body 95 used to store the liquid CO_2. The strength parameters of the tank body 95 is determined according to the depth at which the tank body will be submerged in the seawater. The liquid CO_2 tank comprises a pressure-controlled injection device 91, a pressure-controlled discharge device 92, a satellite positioning device 93, a nitrogen generation device 94, and a pressure-controlled relief device 96. The tank body 95 is capsule-shaped. The capsule-shape helps maintain the stability during the processes of sinking and floating, preventing the liquid CO_2 tank from overturning and facilitating better pressure control. The capsule shape of the tank body is combined with a symmetrical system and thus ensures that the center of gravity is centrally located, but with a slight bias towards the end where the discharge device is situated. The design causes the liquid CO_2 tank to sink vertically along the length of the tank body when submerged, maintaining the stability and orientation of the liquid CO_2 tank.

[0031] The tank body 95 is designed to withstand both the internal pressure and the external pressure exceeding 30bar. Preferably, the tank body 95 is capsule-shaped. The capsule-shape helps maintain the stability during the processes of sinking and floating, preventing the tank from overturning and facilitating better pressure control.

[0032] As the liquid CO_2 tank sinks deeper into the sea, the external pressure from the surrounding seawater increases. When the external pressure becomes greater than the internal pressure of the tank body 95, the pressure-controlled injection device 91 automatically opens in response to the pressure difference. Preferably, the pressure-controlled injection device is used to regulate the rate at which seawater enters the tank body. The regulation is controlled by the size of the opening of the pressure-controlled injection device. A difference between the internal pressure and the external pressure continues to increase as the liquid CO_2 tank sinks deeper. In addition, when a large amount of seawater has flowed into the liquid CO_2 tank, the internal pressure and the external pressure eventually equalize. At the point, the pressure-controlled injection device 91 automatically closes to prevent further seawater from entering the tank body. In addition, the Chinese patent "an industrial bus type LNG fuel security control device for ships" (Patent No. CN201721324589.6) provides a similar injection device. The disclosed pressure-controlled injection device 91 is adapted for use by determining the parameters through simple modifications and testing.

[0033] As the liquid CO_2 tank sinks to a depth of 1000 meters, the external pressure exerted by the surrounding seawater increases significantly. When the external pressure reaches the design pressure of the liquid CO_2 tank, the pressure-controlled discharge device 92 automatically opens in response to the external pressure. Preferably, the nitrogen gas is filled into the liquid CO_2 tank; the pressure-controlled discharge device comprises a gas escape device 97; the gas escape device 97 is used to prevent the liquid CO_2 tank from sinking again if the nitrogen gas escapes. The Chinese patent "an industrial bus type LNG fuel security control device for ships" (Patent No. CN201721324589.6) provides a similar discharge device. The disclosed discharge device 92 is adapted for use by determining the parameters through simple modifications and testing.

[0034] As the liquid CO_2 tank descends, the tank body is heated by the surrounding seawater. The heating causes the temperature of the liquid CO_2 inside the tank body to rise, thus increasing the internal pressure. When the internal pressure exceeds a certain level, the pressure-controlled relief device 96 automatically opens, so as to maintain the internal pressure at a safe level, specifically at 30 bar, by releasing excess pressure. To ensure the structural integrity of the tank body 95 and minimize the need for additional openings in the tank body 95, the pressure-controlled relief device 96 is disposed on the pressure-controlled discharge device 92. The pressure-controlled relief device 96 is similar to a relief device described in the Chinese patent CN202021137650.8, titled "a kind of LPG ship safety relief pipeline device". The disclosed pressure-controlled relief device 96 is adapted for use in the liquid CO_2 tank by determining the parameters through simple modifications and testing.

[0035] When the liquid CO_2 tank sinks to a depth of 1000 meters underwater, the external pressure from the surrounding seawater increases significantly. When the external pressure reaches the design pressure of the tank body 95, the nitrogen generation device 94 automatically activates in response to the external pressure. The nitrogen generation device 94 then generates nitrogen gas through a chemical reaction. Preferably, the nitrogen generation device 94 is similar to a device described in the Chinese patent titled "an emergency rescue device for sunken submarines and surface ships using chemical energy". The disclosed nitrogen generation device 94 is adapted for use by determining the parameters through simple modifications and testing.

[0036] The satellite positioning device 93 is used to locate the liquid CO_2 tank when the liquid CO_2 tank floats to the surface of the sea due to buoyancy.

[0037] The operation process of the liquid CO_2 tank is described in detail:

As shown in FIG. 10, the liquid CO_2 tank is deployed from a bottom hatch of a recovery vessel. The pressure-controlled discharge device 92 is oriented downward, so that the liquid CO_2 tank remains in a vertical orientation. Because the center of gravity is lower, the liquid CO_2 tank remains upright during operation. Since the liquid CO_2 tank is heavier than sea water, the liquid CO_2 tank sinks.

[0038] As the liquid CO_2 tank descends, the seawater at a temperature of above 0°C heats the tank body 95. The heating causes the temperature of the liquid CO_2 inside the liquid CO_2 tank to rise, thus increasing the internal pressure. To manage the increased internal pressure, the pressure-controlled relief device 96 automatically releases the internal pressure and maintain the internal pressure at 30 bar.

[0039] When the liquid CO_2 tank reaches a depth of 300 meters, the external pressure on the tank body 95 becomes 31 bar, which is greater than the internal pressure. To manage the external pressure, the pressure-controlled injection device 91 automatically opens, allowing the seawater to enter the liquid CO_2 tank.

[0040] As the seawater enters the tank body 95, the difference between the internal pressure and the external pressure is reduced. The descent speed of the liquid CO_2 tank is regulated by the resistance from the seawater. When the seawater resistance equals to the weight of the liquid CO_2 tank, the sinking speed stabilizes. The opening size of the pressure-controlled injection device 91 is controlled to regulate the flow rate of the seawater, so as to maintain the pressure difference within 30 bar.

[0041] When the liquid CO_2 tank sinks to a depth of 1000 meters underwater, the pressure difference is adjusted to between 20 - 30 bar or more by controlling the opening size of the pressure-controlled injection device 91. The pressure-controlled discharge device 92 then opens, allowing a large amount of seawater to flow into the liquid CO_2 tank, resulting in equalizing the internal pressure and the external pressure. Subsequently, the pressure-controlled injection device 91 is closed. As shown in FIG. 11, with the pressure difference at zero, the liquid CO_2 flows out of the liquid CO_2 tank due to gravity and dissolves in the seawater, achieving the storage goal at 1000 meters underwater.

[0042] At the same time, the nitrogen generation device 94 activates, producing nitrogen gas through a chemical reaction. The nitrogen gas, being less dense, fills the upper part of the interior of the liquid CO_2 tank, pushing out the seawater and making the liquid CO_2 tank buoyant. The liquid CO_2 tank starts to rise to the surface of the sea. The gas escape device 97 is used to prevent the liquid CO_2 tank from sinking again if nitrogen escapes.

[0043] As shown in FIG. 12, the tank body 95 floats to the surface of the sea due to buoyancy.

[0044] As shown in FIG. 13, the satellite positioning device 93 is used to locate the liquid CO_2 tank.

[0045] As shown in FIG. 14, the bottom hatch of the recovery vessel is then opened; the recovery vessel is used to retrieve the liquid CO_2 tank from the sea; and the liquid CO_2 tank is reused for further processing.

[0046] It will be obvious to those skilled in the art that changes and modifications may be made, and therefore, the aim in the appended claims is to cover all such changes and modifications.

Claims

1. A novel CO_2 maritime transshipment and storage system, comprising:

a. when loading conditions are satisfied, liquid CO_2 is transported from an onshore CO_2 storage terminal to a CO_2 loading device through an onshore pipeline; the CO_2 is then transferred to a CO_2 transport ship; when the CO_2 transport ship reaches a designated sea area, the liquid CO_2 is offloaded via a CO_2 transfer system, conveyed to a CO_2 injection module through the onshore pipeline, and then is injected into an onshore CO_2 storage site or a submarine CO_2 storage site;

when the loading conditions are not satisfied, an alternative procedure, step b or step c, is selected:

b. the liquid CO_2 is transported from the onshore CO_2 storage terminal to a floating CO_2 storage device through a subsea pipeline; the CO_2 transport ship is moored in an inline or side-by-side configuration with the floating CO_2 storage device; the CO_2 is offloaded from CO_2 transport ship to the floating CO_2 storage device via a hose; upon reaching the designated sea area, the CO_2 transport ship is moored in an inline or side-by-side configuration with the floating CO_2 storage device; the floating CO_2 storage device comprises a plurality of internal turrets; the CO_2 is transferred from the CO_2 transport ship to the floating CO_2 storage device through the hose; subsequently, the CO_2 is transmitted to an offshore CO_2 injection platform through the plurality of internal turrets, a subsea pipeline, and an underwater riser; finally, the CO_2 is injected into a submarine CO_2 storage site through a submarine wellhead, ensuring long-term storage; and

c. the CO_2 is transmitted from the onshore CO_2 storage terminal to the floating CO_2 storage device through the subsea pipeline; after the floating CO_2 storage device arrives at the designated sea area, the CO_2 is conveyed to the offshore CO_2 injection platform through the plurality of internal turrets, the subsea pipeline, and the underwater riser; finally, the CO_2 is injected into the submarine CO_2 storage site through a submarine wellhead, ensuring long-term storage.

2. The novel CO_2 maritime transshipment and storage system of claim 1,
wherein the step a, step b, or step c is performed as follows:

S1. injecting liquid CO_2 into a liquid CO_2 tank; where, the liquid CO_2 tank comprises a tank body used to store the liquid CO_2; the tank body comprises a thermal insulation layer; the liquid CO_2 tank further comprises a discharge tank and an injection device; the discharge tank and the injection device are disposed on a first end and a second end of the tank body, respectively; the injection device comprises a unidirectional valve; the center of gravity of the tank body is tilted towards the first end of the tank body; the liquid CO_2 tank further comprises a nitrogen generation device disposed inside the tank body, specifically disposed at the second end of the tank body; the discharge device comprises a pressure-controlled relief device; and the liquid CO_2 tank further comprises a pressure-controlled valve;
S2. transporting, by a ship, the liquid CO_2 tank to an ocean storage area;
S3. releasing the liquid CO_2 tank into the seawater; where, the center of gravity of the tank body is tilted towards the first end of the tank body; the liquid CO_2 tank sinks in a vertical position, with the first end of the tank body facing downward;
S4. opening the pressure-controlled relief device to release the internal pressure when the internal pressure reaches an activation pressure of the pressure-controlled relief device;
S5. opening the injection device to permit the seawater to flow into the liquid CO_2 tank when the external seawater pressure reaches the activation pressure of the injection device;
S6. fully opening both the injection device and the discharge device when the liquid CO_2 tank reaches a designated CO_2 storage depth, and closing the injection device when the liquid CO_2 tank is filled with the seawater; where, the injection device and the discharge device are actuated to an open state, permitting the release of the liquid CO_2 from the liquid CO_2 tank;
S7. activating the nitrogen generation device to produce nitrogen gas, and closing the discharge device to seal the liquid CO_2 tank after the seawater exit the liquid CO_2 tank; where, the nitrogen gas displaces the seawater from the liquid CO_2 tank, making the liquid CO_2 tank buoyant and causing the liquid CO_2 tank to float on the surface of the sea; and
S8. retrieving the liquid CO_2 tank floating on the surface of the sea due to buoyancy.

3. The deep-sea storage method of claim 2, wherein the liquid CO_2 tank achieves a center of gravity that is biased towards the first end of the tank body by attaching a fixed weight.

4. The deep-sea storage method of claim 2, wherein the liquid CO_2 tank further comprises a satellite positioning device used to locate the liquid CO_2 tank when the liquid CO_2 tank floats to the surface of the sea due to buoyancy.

5. The deep-sea storage method of claim 2, wherein the liquid CO_2 tank further comprises a position monitoring device used to determine a depth at which the liquid CO_2 tank has sunk; each of the injection device and the discharge device has a remote control mechanism; the remote control mechanisms allow the injection device and the discharge device to operate respectively when the liquid CO_2 tank sinks to a target depth as detected by the position monitoring device.

6. The deep-sea storage method of claim 2, wherein the liquid CO_2 tank has a maximum allowable pressure of 30 bar.

7. The deep-sea storage method of claim 2, wherein in S6, a minimum depth for CO_2 storage is 1000 meters underwater.

8. The deep-sea storage method of any one of claims 1-7, wherein when the CO_2 is in a liquid state, the pressure within a set of pipelines ranges from 0.4 MPa to 7.39 MPa; when the CO_2 is in a supercritical state, the CO_2 in the set of pipelines is maintained at temperatures above 31.3°C, with the pressure exceeding 7.39 MPa; when the CO_2 is in a gaseous state, the pressure within the set of pipelines ranges from 0 to 7.39 MPa; and
the CO_2 transport ship comprises a C-type tank for storage; and the CO_2 transport ship is used to contain the CO_2 at pressures ranging from 0.4 MPa to 2.1 MPa.

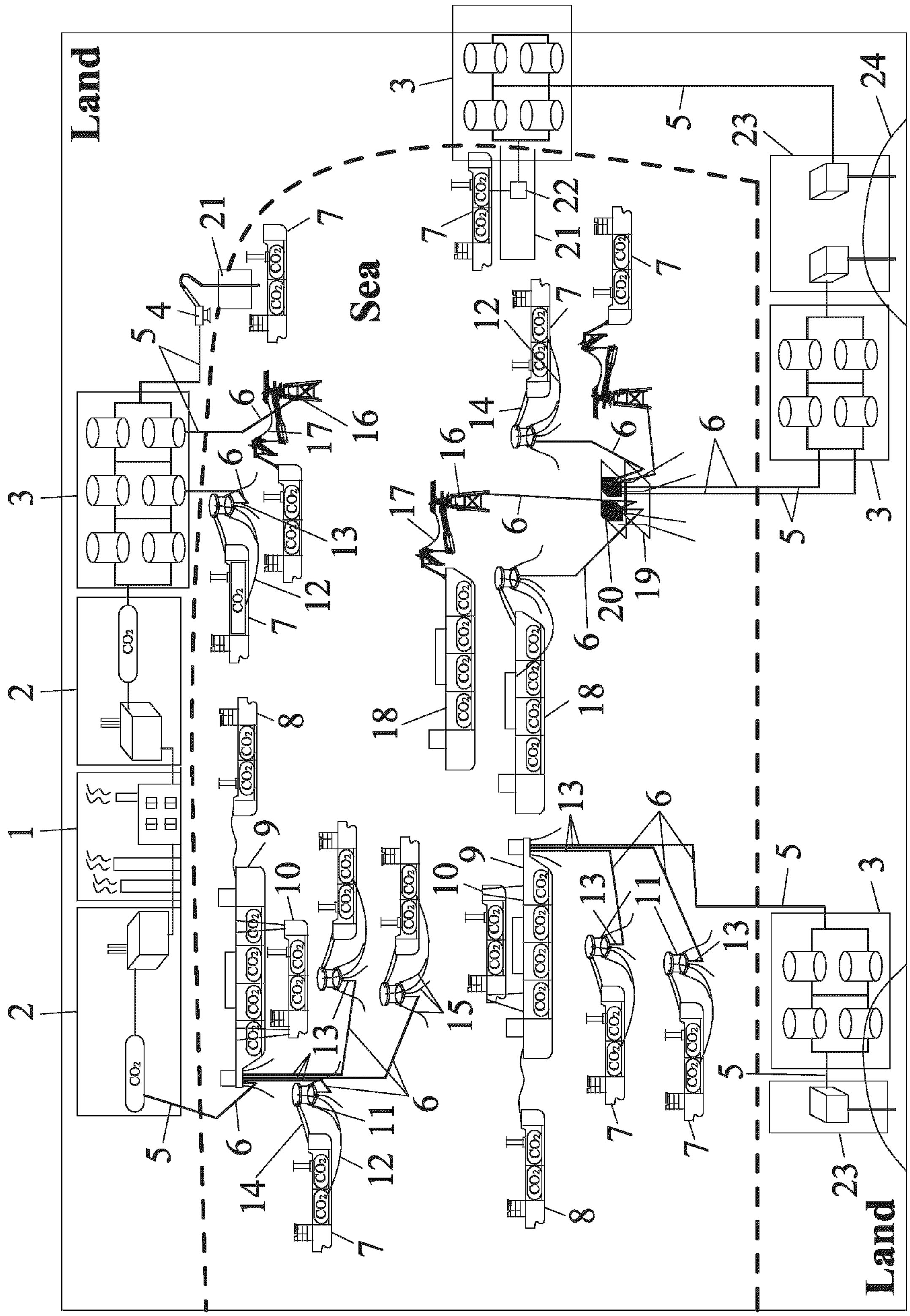

FIG. 1

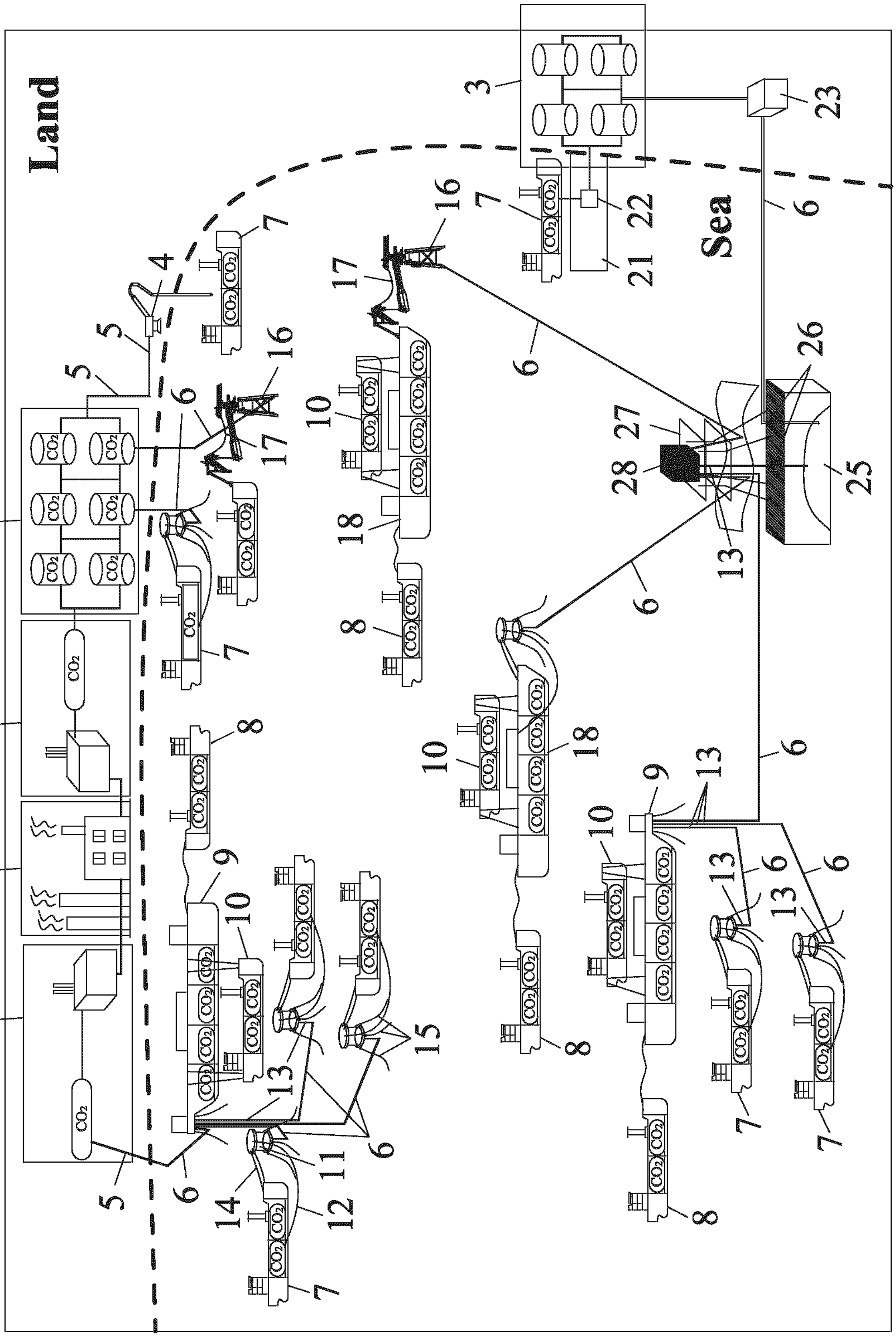

FIG. 2

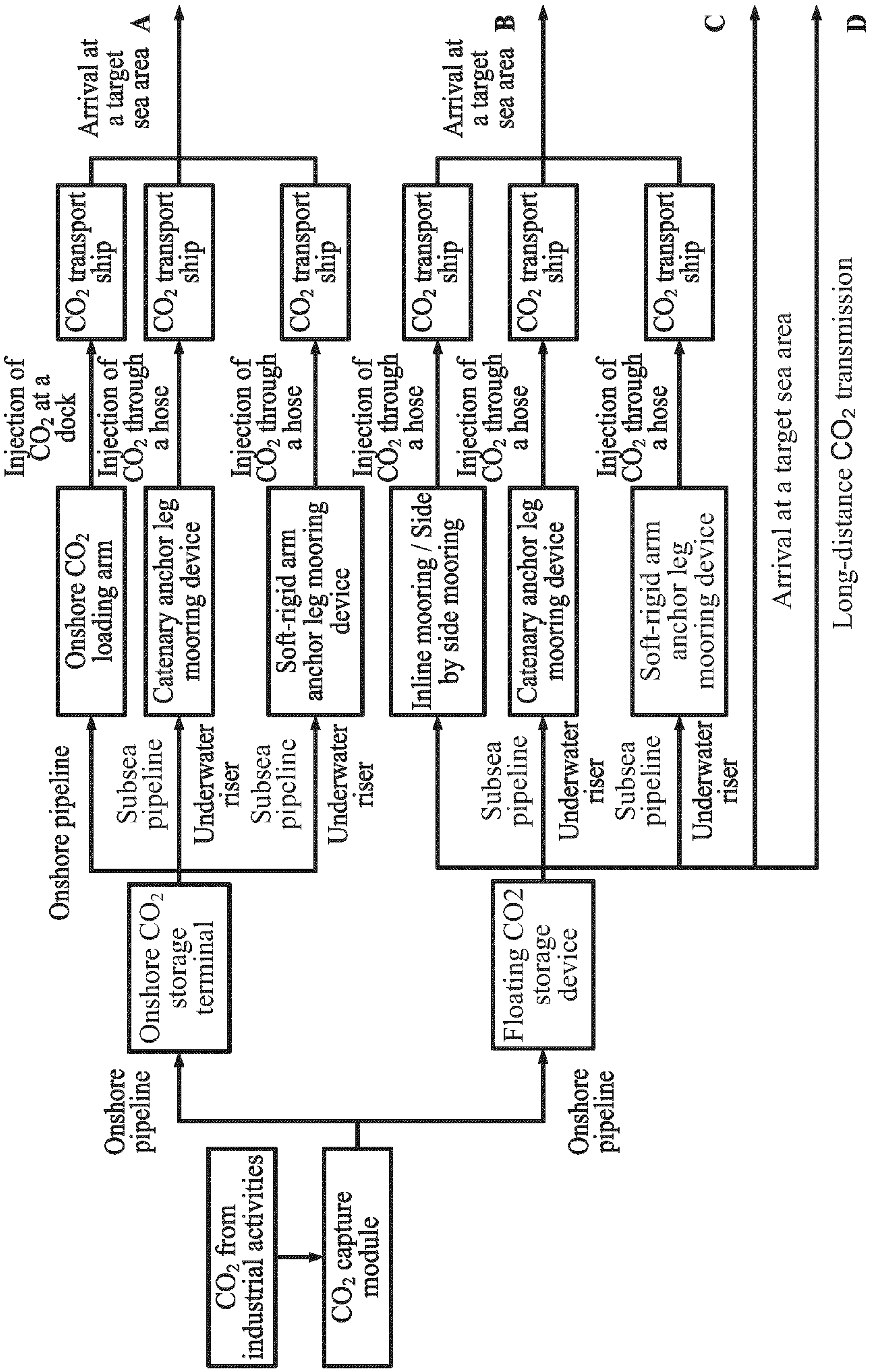
CO_2 from industrial activities
CO_2 capture module
Onshore pipeline
Onshore pipeline
Onshore CO_2 storage terminal
Floating CO2 storage device
Onshore pipeline
Subsea pipeline
Underwater riser
Subsea pipeline
Underwater riser
Subsea pipeline
Underwater riser
Subsea pipeline
Underwater riser
Onshore CO_2 loading arm
Catenary anchor leg mooring device
Soft-rigid arm anchor leg mooring device
Inline mooring / Side by side mooring
Catenary anchor leg mooring device
Soft-rigid arm anchor leg mooring device
Injection of CO_2 at a dock
Injection of CO_2 through a hose
Injection of CO_2 through a hose
Injection of CO_2 through a hose
Injection of CO_2 through a hose
Injection of CO_2 through a hose
CO_2 transport ship
CO_2 transport ship
CO_2 transport ship
CO_2 transport ship
CO_2 transport ship
CO_2 transport ship
Arrival at a target sea area
A
Arrival at a target sea area
B
Arrival at a target sea area
C
Long-distance CO_2 transmission
D

FIG. 3

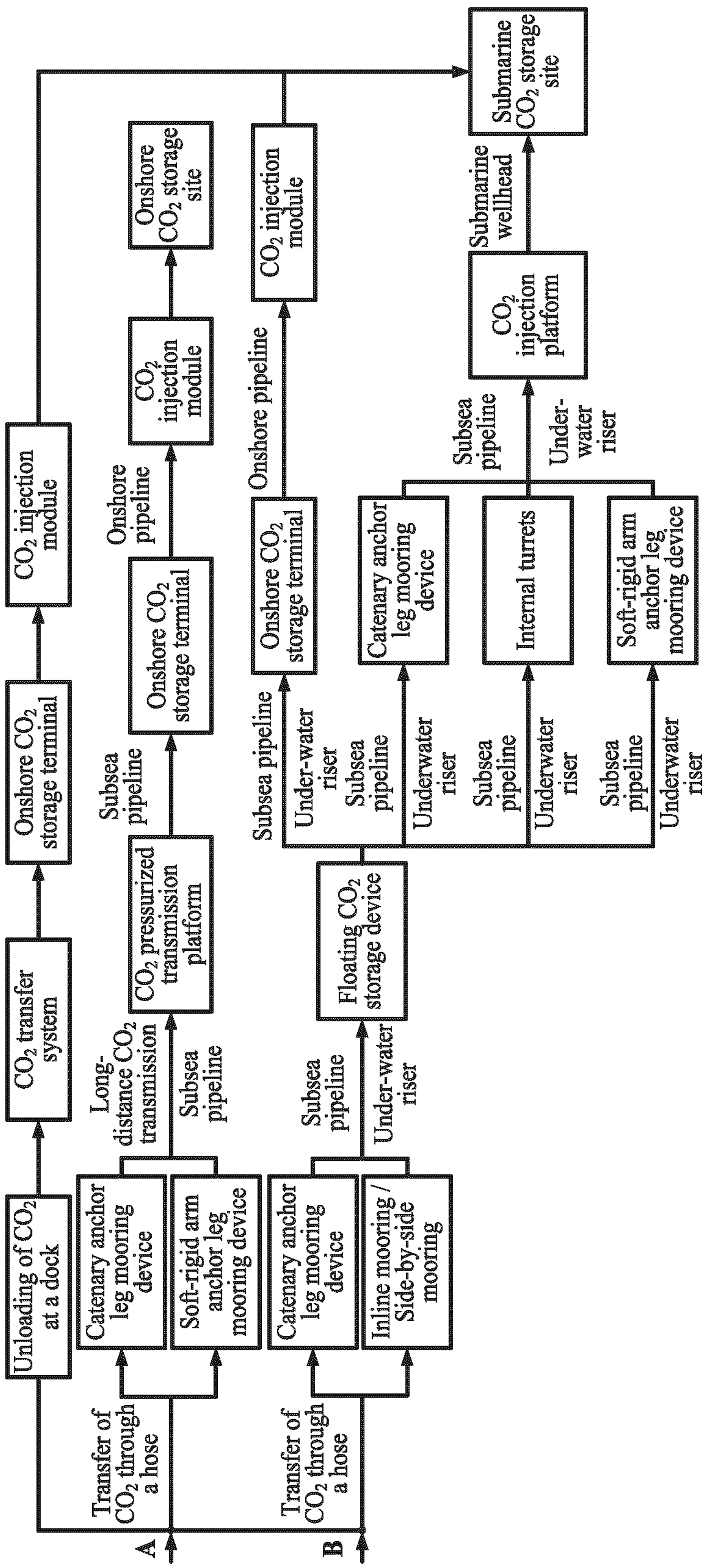
A
B
Transfer of CO_2 through a hose
Transfer of CO_2 through a hose
Unloading of CO_2 at a dock
CO_2 transfer system
Onshore CO_2 storage terminal
CO_2 injection module
Catenary anchor leg mooring device
Soft-rigid arm anchor leg mooring device
Long-distance CO_2 transmission
Subsea pipeline
CO_2 pressurized transmission platform
Subsea pipeline
Onshore CO_2 storage terminal
Onshore pipeline
CO_2 injection module
Onshore CO_2 storage site
Catenary anchor leg mooring device
Inline mooring / Side-by-side mooring
Subsea pipeline
Under-water riser
Floating CO_2 storage device
Subsea pipeline
Under-water riser
Onshore CO_2 storage terminal
Onshore pipeline
CO_2 injection module
Subsea pipeline
Underwater riser
Catenary anchor leg mooring device
Subsea pipeline
Underwater riser
Internal turrets
Subsea pipeline
Underwater riser
Soft-rigid arm anchor leg mooring device
Subsea pipeline
Under-water riser
CO_2 injection platform
Submarine wellhead
Submarine CO_2 storage site

FIG. 4

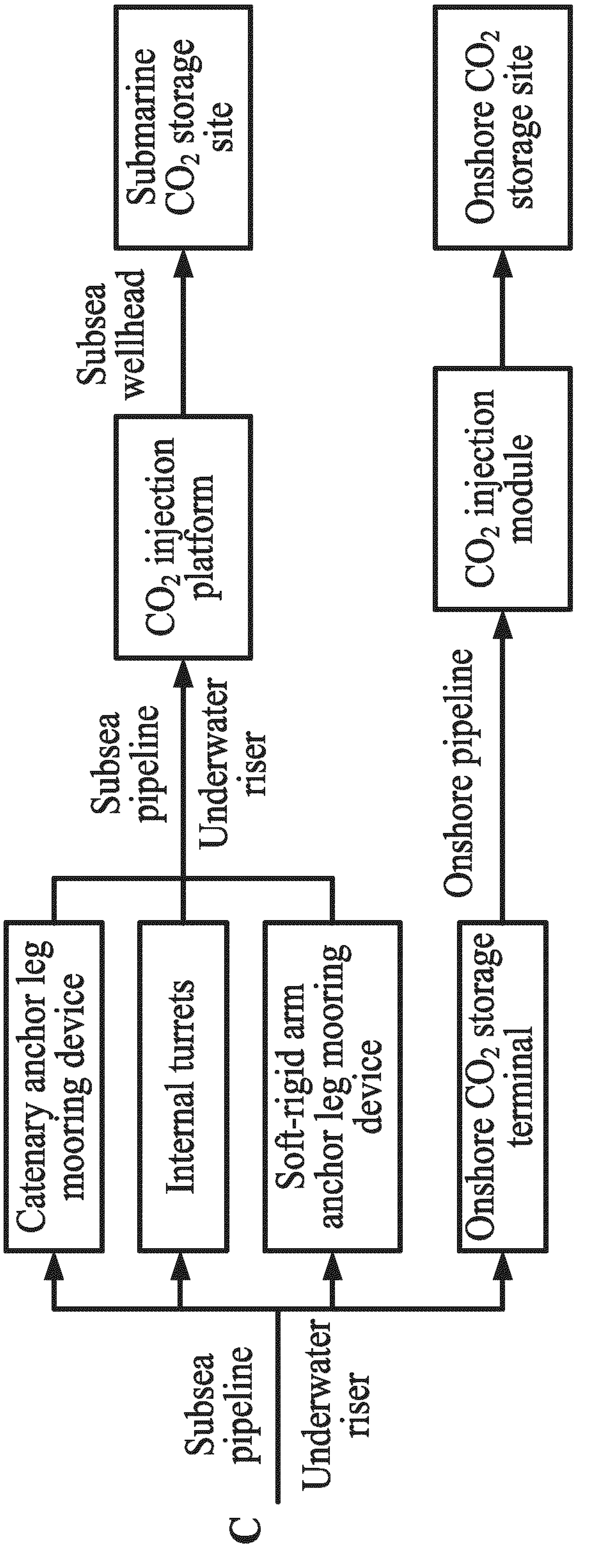
C
Subsea pipeline
Underwater riser
Catenary anchor leg mooring device
Internal turrets
Soft-rigid arm anchor leg mooring device
Onshore CO_2 storage terminal
Subsea pipeline
Underwater riser
Onshore pipeline
CO_2 injection platform
CO_2 injection module
Subsea wellhead
Submarine CO_2 storage site
Onshore CO_2 storage site

FIG. 5

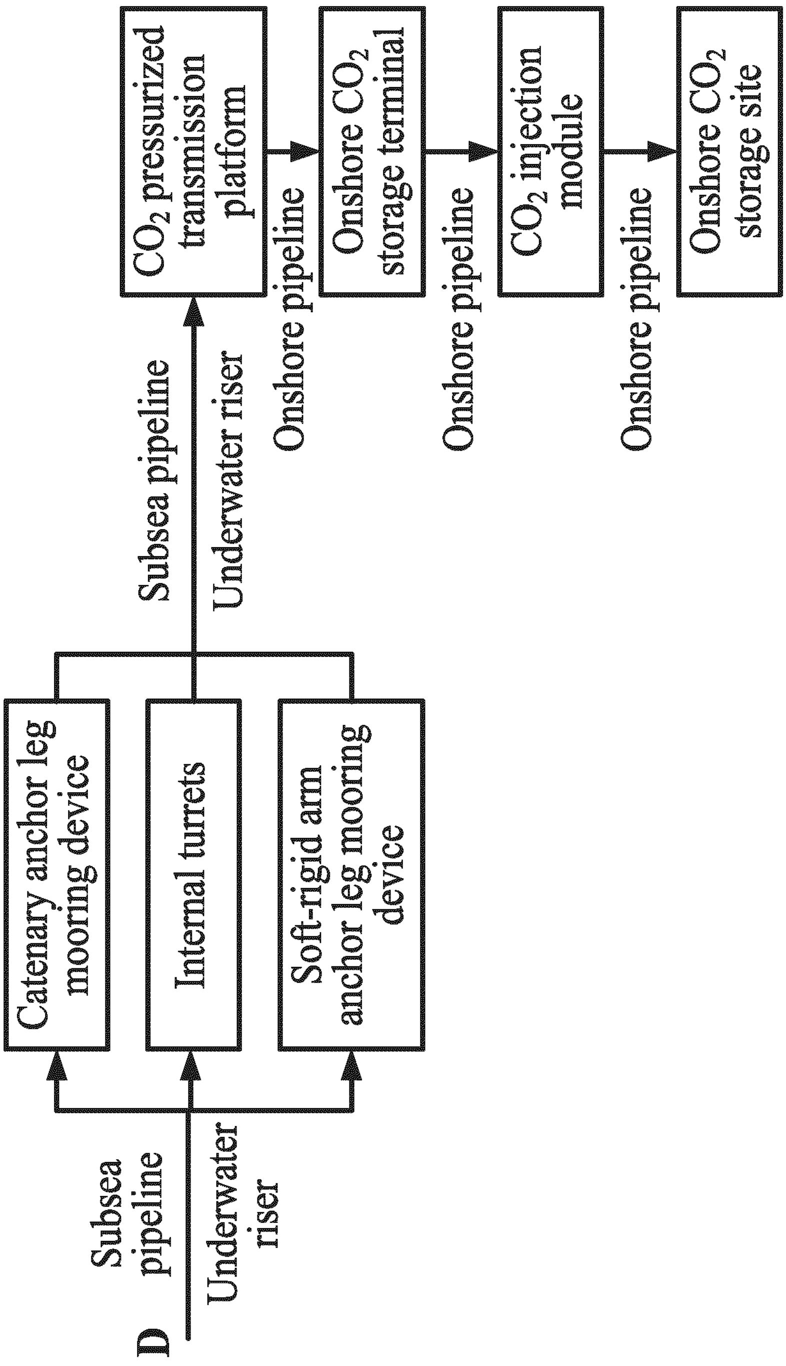
D
Subsea pipeline
Underwater riser
Catenary anchor leg mooring device
Internal turrets
Soft-rigid arm anchor leg mooring device
Subsea pipeline
Underwater riser
CO_2 pressurized transmission platform
Onshore pipeline
Onshore CO_2 storage terminal
Onshore pipeline
CO_2 injection module
Onshore pipeline
Onshore CO_2 storage site

FIG. 6

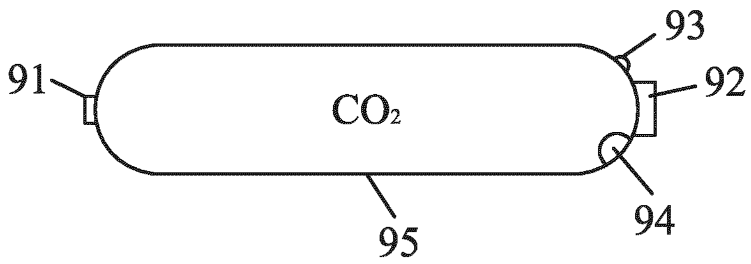

FIG. 7

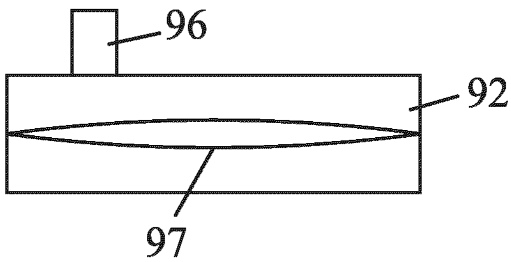

FIG. 8

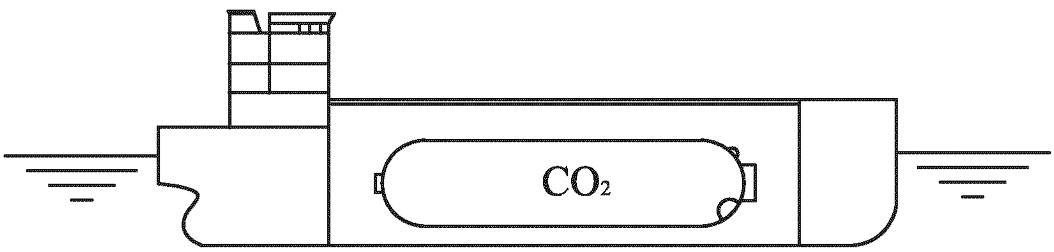

FIG. 9

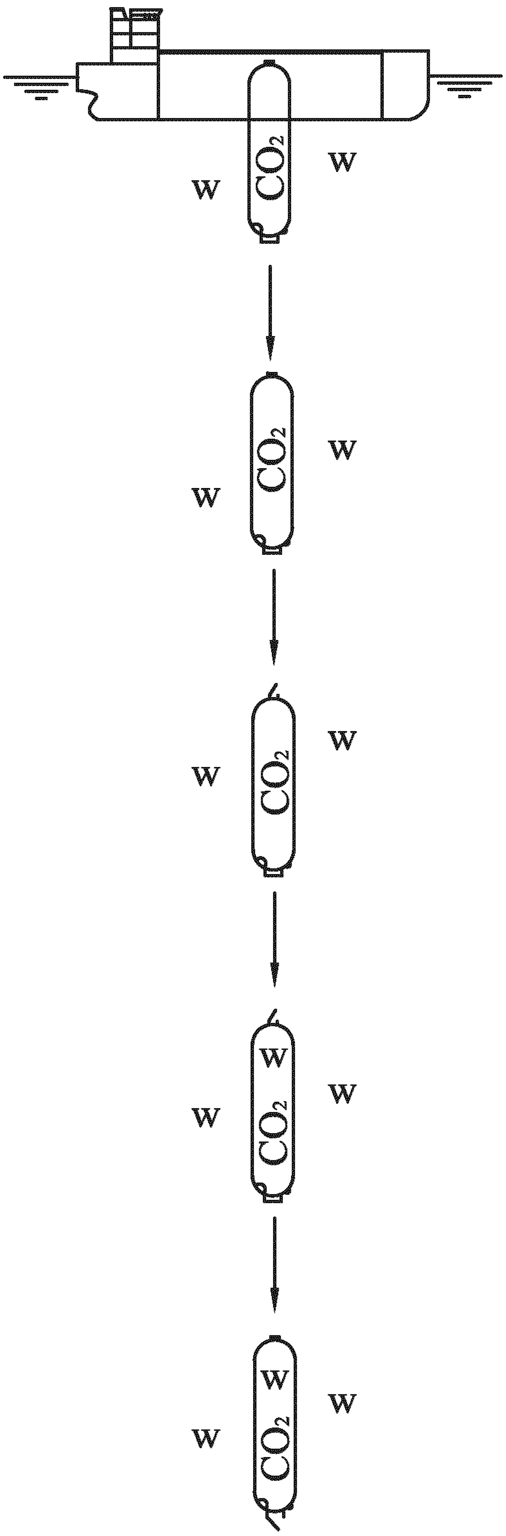

FIG. 10

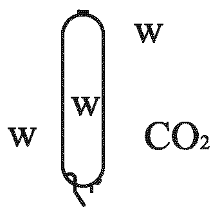

FIG. 11

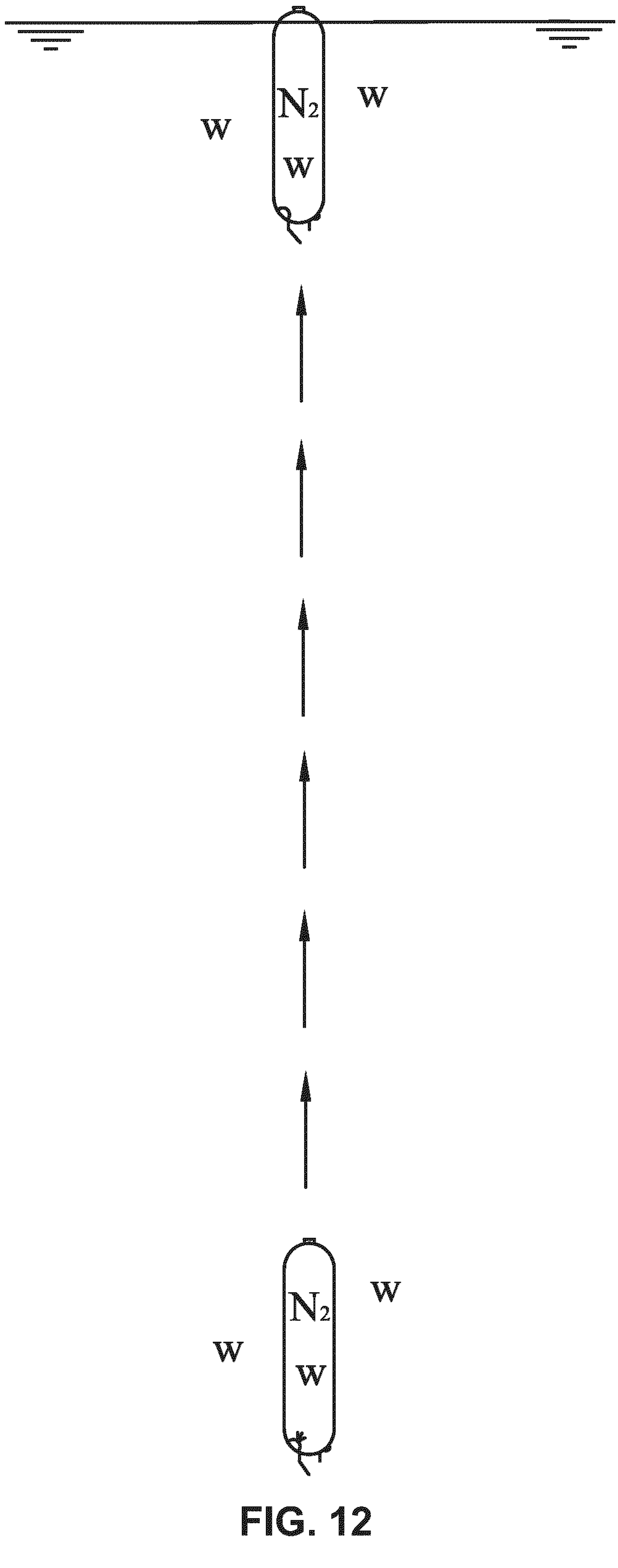

FIG. 12

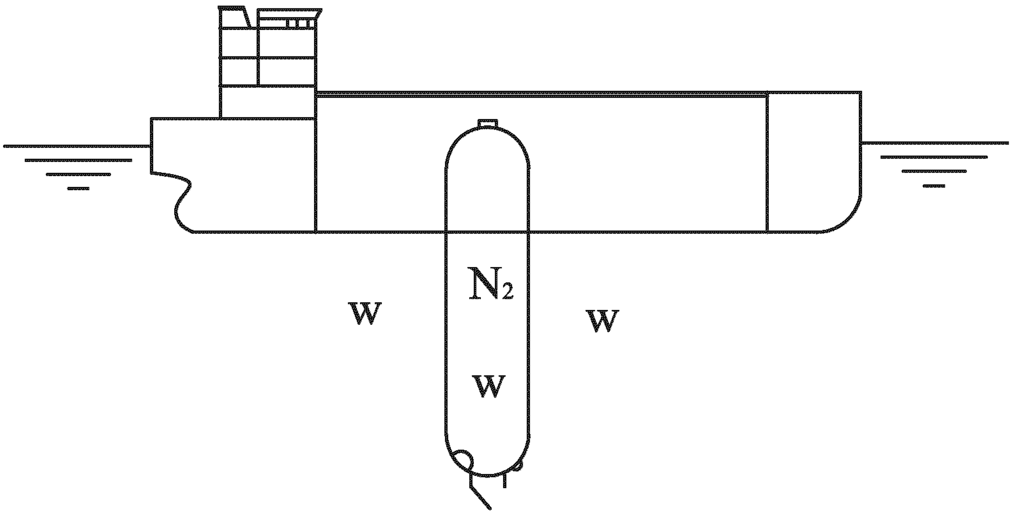

FIG. 13

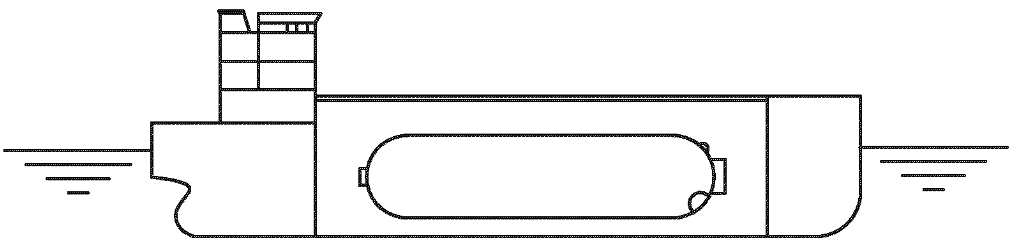

FIG. 14

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2023/072515

A. CLASSIFICATION OF SUBJECT MATTER

B65B25/12(2006.01)i;B63B35/44(2006.01)i;B63B27/34(2006.01)i

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)

IPC: B65B

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

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

CNTXT, VEN, CNKI: 二氧化碳, 转运, 封存, 船, 浮式, 码头, 管道, 输送, 罐, carbon dioxide, transport, ship, float, storage, container, harbor, dock

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2011019096 A1 (KOREA MARITIME & OCEAN ENGINEERING RESEARCH INSTITUTE et al.) 17 February 2011 (2011-02-17) description, embodiments, and figures 1-7	1-8
A	JP 2011031230 A (HAGA GUNJI) 17 February 2011 (2011-02-17) entire document	1-8
A	US 2017283014 A1 (MIRADE CONSULTANTS LTD.) 05 October 2017 (2017-10-05) entire document	1-8
A	WO 2018234721 A1 (MIRADE CONSULTANTS LTD.) 27 December 2018 (2018-12-27) entire document	1-8
A	徐冬等 (XU, Dong et al.). "CCUS中CO2运输环节的技术及经济性分析 (Technical and Economic Analysis on CO2 Transportation Link in CCUS)" *国际石油经济 (International Petroleum Economics),* Vol. 29, No. 6, 30 June 2021 (2021-06-30), pages 9-11	1-8

☐ Further documents are listed in the continuation of Box C.

☑ See patent family annex.

* Special categories of cited documents:
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- "D" document cited by the applicant in the international application
- "E" earlier application or patent but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "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
05 May 2023	**16 May 2023**

Name and mailing address of the ISA/CN	Authorized officer
China National Intellectual Property Administration (ISA/CN) **China No. 6, Xitucheng Road, Jimenqiao, Haidian District, Beijing 100088**	Telephone No.

Form PCT/ISA/210 (second sheet) (July 2022)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2023/072515

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		GB 2484635 A	18 April 2012
		GB 2484635 B	15 January 2014
JP 2011031230 A	17 February 2011	None	
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		BR 112019027357 A2	07 July 2020
		BR 112019027357 B1	22 November 2022
		BR 112019027357 B8	21 March 2023

Form PCT/ISA/210 (patent family annex) (July 2022)

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- CN 201721324589 **[0032] [0033]**
- CN 202021137650 **[0034]**