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(71) Demandeur/Applicant:
MARATHON PETROLEUM COMPANY LP, US

(72) Inventeur/Inventor:
THOBE, ZACHARY D., US

(74) Agent: ROBIC AGENCE PI S.E.C./ROBIC IP AGENCY LP

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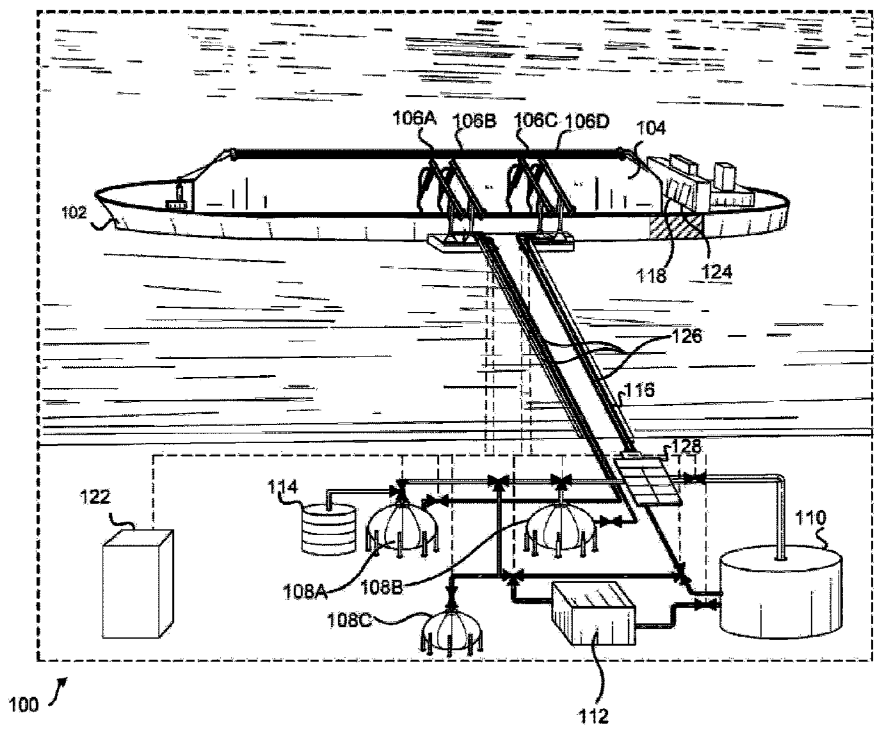
(54) Title: SYSTEMS AND METHODS FOR BACKHAUL TRANSPORTATION OF LIQUEFIED GAS AND CO2 USING LIQUEFIED GAS CARRIERS



(57) Abrégé/Abstract:
Embodiments of systems and methods for transporting liquefied gas and carbon dioxide (CO_2) in a dual-fluid vessel thereby minimizing transportation between locations are disclosed. In an embodiment, the dual-fluid vessel has an outer shell with an outer surface, an outer compartment within the outer shell configured to store liquefied gas, a bladder positioned within the outer compartment configured to store CO_2, and insulation positioned between the outer shell and the outer compartment to provide temperature regulation for the liquefied gas when positioned in the outer compartment and CO_2 in the bladder.

ABSTRACT

Embodiments of systems and methods for transporting liquefied gas and carbon dioxide (CO_2) in a dual-fluid vessel thereby minimizing transportation between locations are disclosed. In an embodiment, the dual-fluid vessel has an outer shell with an outer surface, an outer compartment within the outer shell configured to store liquefied gas, a bladder positioned within the outer compartment configured to store CO_2, and insulation positioned between the outer shell and the outer compartment to provide temperature regulation for the liquefied gas when positioned in the outer compartment and CO_2 in the bladder.

Date Reçue/Date Received 2023-08-18

SYSTEMS AND METHODS FOR BACKHAUL TRANSPORTATION OF LIQUEFIED GAS AND CO2 USING LIQUEFIED GAS CARRIERS

FIELD OF DISCLOSURE

[0001] The present disclosure relates to systems and methods for dual-fluid storage of a liquid or gaseous commodity and carbon dioxide. More specifically, the present disclosure relates to methods and systems for transporting a liquid or gaseous commodity and carbon dioxide using liquefied gas carriers.

BACKGROUND

[0002] Carbon capture and storage or utilization is an important technological approach to reduce carbon from entering the atmosphere and can be applied to many energy industries. Carbon capture and storage typically involves three steps including: (1) capturing the carbon dioxide, (2) transporting the captured carbon dioxide, and (3) storing the carbon dioxide. Countries have differing standards on requirements needed to reduce the amount of greenhouse gases released into the atmosphere. Growing demand for the reduction of greenhouse gases provides market opportunity to transport captured carbon across different continents and to different countries, which have either suitable geological specifications to permanently sequester carbon or developed technology to utilize the carbon to manufacture useful products. Liquefied gas shipping carriers to transport hydrocarbons, such as liquefied natural gas (LNG) and/or liquefied petroleum gas (LPG), are often used to transport those hydrocarbon commodities at scale. The liquefied gas carriers transport the hydrocarbon fluids stored therein to a location with demand; however, the liquefied gas carriers typically returns empty.

SUMMARY OF THE DISCLOSURE

[0003] Provided here are systems and methods to address these shortcomings of the art and provide other additional or alternative advantages. The disclosure herein provides several embodiments of a liquefied gas carrier configured to transport liquefied gas and carbon dioxide (CO_2). An embodiment of the liquefied gas carrier includes one or more dual-fluid storage tanks positioned on a liquefied gas carrier to transport liquefied gas and/or CO_2. The one or more dual-fluid storage tanks have (i) an outer shell, (ii) an outer compartment positioned within the outer shell configured to store the liquefied gas (or, in some embodiments, CO_2), and (iii) a bladder positioned within the outer compartment configured to expand when the CO_2 (or, in some

Date Reçue/Date Received 2023-08-18

embodiments, liquefied gas) flows therein, thereby to reduce contamination between the CO_2 and the liquefied gas. Insulation is positioned between the outer shell and the outer compartment to provide temperature regulation from external heat sources to reduce boil off of the liquefied gas when positioned in the outer compartment and CO_2 in the bladder.

[0004] In certain embodiments, a pressure and temperature rating for the one or more dual-fluid storage tanks comprises about 80 pounds per square inch gauge (psig) to about 102 psig maximum pressure and about -260 degrees Fahrenheit minimum temperature. In certain embodiments, the one or more dual-fluid storage tanks comprises one or more of spherical tanks, refrigerated tanks, prismatic tanks, cylindrical tanks, or bilobe tanks. In certain embodiments, the one or more dual-fluid storage tanks include one or more temperature-control apparatuses. In certain embodiments, the one or more dual-fluid storage tanks include one or more pressure-control apparatuses. In certain embodiments, the bladder contracts when fluid flows therefrom. In certain embodiments, if the bladder is partially or substantially empty, the outer compartment fills with nitrogen to stabilize the bladder. In certain embodiments, the one or more dual-fluid storage tanks further include one or more membranes, waffles, or baffles positioned within each of the one or more dual-fluid storage tanks.

[0005] In another embodiment, a dual-fluid transport system for transporting liquefied natural gas (LNG) and CO_2 includes an LNG carrier configured to transport LNG and CO_2. The LNG carrier includes one or more dual-fluid storage tanks positioned on the LNG carrier to transport the LNG and/or the CO_2. The one or more dual-fluid storage tanks have (i) an outer shell, (ii) an outer compartment positioned within the outer shell configured to store the LNG, and (iii) a bladder positioned within the outer compartment to expand when the CO_2 flows therein, thereby to reduce contamination between the CO_2 and the LNG. Insulation is positioned between the outer shell and the outer compartment to provide temperature regulation from external heat sources to reduce boil off of the LNG when positioned in the outer compartment and CO_2 in the bladder. One or more pumps are configured to pump the LNG from the one or more dual-fluid storage tanks. One or more articulated rigid loading arms are positioned at a location to connect the LNG carrier to the location. The one or more articulated rigid loading arms are configured to load and unload the LNG including (i) a vapor return line configured to return excess vapor from the LNG to the location and (ii) a dehydration unit connected to the one or more articulated rigid loading arms and configured to remove water from the CO_2 when the CO_2 is loaded onto the LNG carrier. In certain

Date Reçue/Date Received 2023-08-18

embodiments, the one or more dual-fluid storage tanks comprises about 80 pounds per square inch gauge (psig) to about 102 psig maximum pressure and about -260 degrees Fahrenheit minimum temperature. In certain embodiments, the one or more dual-fluid storage tanks comprises one or more of spherical tanks, refrigerated tanks, prismatic tanks, cylindrical tanks, or bilobe tanks. In certain embodiments, the one or more dual-fluid storage tanks include one or more temperature-control apparatuses. In certain embodiments, the one or more dual-fluid storage tanks include one or more pressure-control apparatuses. In certain embodiments, the bladder contracts when fluid flows therein. In certain embodiments, if the bladder is partially or substantially empty, the outer compartment fills with nitrogen to stabilize the bladder. In certain embodiments, the one or more dual-fluid storage tanks further includes one or more membranes, waffles, or baffles positioned within each of the one or more dual-fluid storage tanks. In certain embodiments, the one or more dual-fluid storage tanks further comprises one or more sensors, the one or more sensors determine a temperature or a pressure of the LNG and the CO_2. In certain embodiments, a liquefaction unit is also positioned at the location to transfer the CO_2 to the LNG carrier.

[0006] In another embodiment, a method of unloading/loading liquefied gas and CO_2 at a location includes the steps of aligning one or more articulated rigid loading arms positioned at a location with one or more dual-fluid storage tanks positioned on a liquefied gas carrier. The one or more dual-fluid storage tanks are positioned on a liquefied gas carrier. The one or more dual-fluid storage tanks include an outer compartment configured to store liquefied gas and a bladder connected to a wall within the outer compartment configured to store CO_2. The method also includes the step of connecting each of the one or more articulated rigid loading arms, via a first controller, to the outer compartment or the bladder of each of the one or more dual-fluid storage tanks. If the outer compartment contains liquefied gas, in response to reception of a first liquefied gas pump operation signal from the first controller and a second liquefied gas pump operation signal from a second controller, the method further includes pumping a first liquefied gas from the outer compartment to one or more liquefied gas storage tanks and one of (a) a second liquefied gas from one or more liquefied gas storage tanks to the outer compartment or (b) CO_2 from one or more CO_2 storage tanks to the bladder. If the bladder contains CO_2, in response to reception of a first CO_2 signal from the first controller and a signal from a second CO2 signal from the second controller, the method further includes pumping CO_2 from the bladder to one or more CO_2 storage

Date Reçue/Date Received 2023-08-18

tanks at the location and the second liquefied gas from one or more liquefied gas storage tanks to the outer compartment.

[0007] In another embodiment, a controller for a liquefied gas carrier for transporting liquefied gas and CO_2 includes a first input/output in signal communication with one or more temperature-control apparatuses. The controller is positioned within an outer compartment of each of one or more dual-fluid storage tanks on a liquefied gas carrier and a bladder positioned within the outer compartment. The controller is configured to obtain a first temperature of a liquefied gas contained within the outer compartment and a second temperature of CO_2 contained within the bladder during unloading operations, unloading operations, and transport of the liquefied gas and CO_2. The controller also includes a second input/output in signal communication with one or more pressure-control apparatuses positioned within the outer compartment of each of one or more dual-fluid storage tanks and the bladder. The controller is configured to obtain a first pressure of the liquefied gas contained within the outer compartment and a second pressure of CO_2 contained within the bladder during the unloading operations, the loading operations, and the transport of the liquefied gas and CO_2. The controller also includes a third input/output in signal communication with a first flow meter positioned at a first inlet of the outer compartment and a second flow meter positioned at a second inlet of the bladder. The controller is configured to measure a first flow rate of the liquefied gas and a second flow rate of the CO_2. The controller further includes a fourth input/output in signal communication with a first control valve. The first control valve is designed to adjust flow of the liquefied gas via one or more unloading/loading pumps positioned on the liquefied gas carrier thereby modifying the first flow rate of the liquefied gas and a second control valve. The second control valve is designed to adjust flow of the CO_2 via the one or more unloading/loading pumps thereby modifying the second flow rate. The controller is configured to, after initiation of the unloading operations or the loading operations, determine whether the first flow rate or the second flow rate will be modified based on an outer compartment temperature, an outer compartment pressure, a bladder pressure, or a bladder temperature. In response to a determination that the first flow rate is to be modified, the controller adjusts a position of the first flow control valve that adjusts flow of the liquefied gas, thereby modifying the first flow rate. The controller may also in response to a determination that the second flow rate is to be modified adjust a position of the second flow control valve that adjusts flow of the CO_2, thereby modifying the second flow rate.

Date Reçue/Date Received 2023-08-18

[0008] The controller may make a determination of whether the first flow rate or the second flow rate will be modified based on a first amount of the liquefied gas within the outer compartment and a second amount of the CO_2 within the bladder. The controller may make a determination of whether the first flow rate or the second flow rate are to be modified is based on a third amount of the liquefied gas within one or more liquefied gas storage tanks positioned at a location and a second amount of the CO_2 within one or more CO_2 storage tanks.

BRIEF DESCRIPTION OF DRAWINGS

[0009] These embodiments and other features, aspects, and advantages of the disclosure will be better understood in conjunction with the following descriptions, claims, and accompanying drawings. It is to be noted, however, that the drawings illustrate only certain embodiments of the disclosure and, therefore, are not to be considered limiting of the scope of the disclosure. The disclosure includes any combination of one or more features or elements set forth in this disclosure or recited in any one or more of the claims, regardless of whether such features or elements are expressly combined or otherwise recited in a specific embodiment description or claim herein. This disclosure is intended to be read holistically such that any separable features or elements of the disclosure, in any of its aspects and embodiments, should be viewed as intended to be combinable, unless the context of the disclosure clearly dictates otherwise.

[0010] FIG. 1 is an illustrative diagram of a prismatic liquefied gas carrier stationed at a terminal, according to an embodiment of the disclosure.

[0011] FIG. 2 is an illustrative diagram of a spherical liquefied gas carrier, according to an embodiment of the disclosure.

[0012] FIG. 3A is an illustrative diagram of a prismatic tank with a vertically expanding inner bladder, according to an embodiment of the disclosure.

[0013] FIG. 3B is an illustrative diagram of a prismatic tank with a horizontally expanding inner bladder, according to an embodiment of the disclosure.

[0014] FIG. 3C is an illustrative diagram of a spherical tank with a vertically expanding inner bladder, according to an embodiment of the disclosure.

Date Reçue/Date Received 2023-08-18

[0015] FIG. 4A-4H are illustrative diagrams of different phases of unloading/loading liquefied gases and CO2 within one or more dual-fluid storage tanks, according to an embodiment of the disclosure.

[0016] FIG. 5 is an illustrative diagram of a spherical liquefied gas carrier stationed at a terminal, according to an embodiment of the disclosure.

[0017] FIG. 6 is a simplified block diagram for unloading/ loading liquefied gas and carbon dioxide in an LNG carrier, according to an embodiment of the disclosure.

[0018] FIG. 7A-7C are flow diagrams that illustrate a controller for unloading/loading liquefied gas and carbon dioxide in a liquefied gas carrier, according to an embodiment of the disclosure.

[0019] FIG. 8 is a simplified diagram implemented in a controller, for controlling unloading and onloading operations, according to an embodiment of the disclosure.

DETAILED DESCRIPTION

[0020] So that the manner in which the features and advantages of the embodiments of the systems and methods disclosed herein, as well as others, which will become apparent, may be understood in more detail, a more particular description of embodiments of systems and methods briefly summarized above may be had by reference to the following detailed description of embodiments thereof, in which one or more are further illustrated in the appended drawings, which form a part of this specification. It is to be noted, however, that the drawings illustrate only various embodiments of the embodiments of the systems and methods disclosed herein and are therefore not to be considered limiting of the scope of the systems and methods disclosed herein as it may include other effective embodiments as well.

[0021] Although specific terms are employed herein, the terms are used in a descriptive sense only and not for purposes of limitation. Embodiments of systems and methods have been described in considerable detail with specific reference to the illustrated embodiments. However, it will be apparent that various modifications and changes can be made within the spirit and scope of the embodiments of systems and methods as described in the foregoing specification, and such modifications and changes are to be considered equivalents and part of this disclosure.

[0022] Provided here are systems and methods to address these shortcomings of the art and provide other additional or alternative advantages. The disclosure herein provides several

Date Reçue/Date Received 2023-08-18

embodiments of a liquefied gas carrier configured to transport liquefied gas and carbon dioxide (CO_2) in a dual-transport system. The liquefied gas carrier may be a new build or a retrofit of an existing vessel. A liquefied gas carrier may transport liquefied gas to a location and transport CO_2 from the same location back to the original location. In this manner, the liquefied gas carrier maximizes the available capacity in all phases of transport. In certain embodiments, the liquefied gas carrier may be a liquefied petroleum gas (LPG) carrier or a liquefied natural gas (LNG) carrier configured to transport liquefied gas and CO_2. The liquefied gas may be LNG, LPG, liquid nitrogen, liquid air, or other types of liquefied gases transported via such carriers. In certain embodiments, as illustrated in **FIGS. 1-8**, for example, the present disclosure is directed to systems and methods for transporting liquefied gas and CO_2 on a liquefied gas carrier.

[0023] A liquefied gas carrier may contain or include one or more dual-fluid storage tanks. Each of the one or more dual-fluid storage tanks may have (a) a prismatic design, (b) a membrane design, or (c) a moss spherical design. A moss spherical design may use hull space more efficiently than other tank designs. Additionally, the moss spherical design may withstand higher pressure and utilize a lesser metal hull or wall thickness than cylinders while handling the same or even higher pressures. The liquefied gas carrier may have five spheres, tanks, or containers. In other embodiments, the liquefied gas carrier may include more or fewer than five spheres. Each sphere, tank, or container may be designed to be about 1.5 inches thick (for example, as described in American Society of Mechanical Engineers (ASME) VIII code) with a diameter from about 100 feet (ft) to about 140 ft and weigh about 1400 megatons (MT) each. This includes about 1/8 inch of corrosion allowance and an about 5% overage to account for support structure. Each sphere, tank, or container may be designed to hold a volume of about 150,000 cubic meters (m^3).

[0024] Other configurations of the dual-fluid storage tanks may include refrigerated tanks, cylindrical tanks, and bilobe tanks. The material used in the one or more dual-fluid storage tanks design may be aluminum, balsa wood, plywood, invar, nickel steel, and/or stainless steel, such as 517 A. The design and material of the one or more dual-fluid storage tanks may be chosen or selected depending on a specified temperature and pressure of the liquid gas and CO_2 during transportation.

[0025] The one or more dual-fluid storage tanks may be fully pressurized tanks, semi-pressurized tanks, fully refrigerated tanks, or some combination thereof. A carrier with fully pressurized tanks

Date Reçue/Date Received 2023-08-18

may include a number of horizontal cylindrical or spherical tanks that are fitted to carry large amounts of gas. Semi-pressurized tanks may carry liquid gases at low temperatures as compared to other configurations or types of tanks. Such semi-pressurized tanks may be cylindrical, spherical, or bilobe tanks in shape. Refrigerated tanks may carry liquefied gas at even lower temperatures and maintain such temperatures during transport. Refrigerated tanks may be prismatic in shape.

[0026] In embodiments, the one or more dual-fluid storage tanks may be classified as an independent Type 'A', independent Type 'B', independent Type 'C', or membrane type tanks. Independent Type 'A' are fully refrigerated tanks, independent Type 'B' are spherical or prismatic tanks that have a partial secondary barrier for a fail-safe design, independent Type 'C' are fully pressurized tanks, and membrane are non-self-supported tanks surrounded by a complete double hull structure.

[0027] FIG. 1 is an illustrative diagram of a prismatic LNG carrier stationed at a terminal. In certain embodiments, the dual-fluid transport system **100** includes or comprises a liquefied gas carrier, such as an LNG carrier or liquefied gas carrier **102** configured to transport LNG (and/or, in some embodiments, other liquefied gases) and CO_2. The LNG carrier contains or includes one or more dual-fluid storage tanks **104** positioned at and/or along a center-line of the LNG carrier and configured to store and transport the LNG and/or the CO_2. The liquefied gas carrier **102** may be configured to maximize the liquefied gas carrier's capacity to transport liquefied gas and CO_2, thereby improving transportation efficiency. The liquefied gas carrier **102** may transport liquefied gas, CO_2, or both at all times. The liquefied gas carrier may deliver liquefied gas and/or CO_2 to a location and may return with a different liquefied gas and/or CO_2. Typically, the liquefied gas carrier **102** returns empty after delivery of the liquefied gas, which wastes time, money, and, further, is not carbon neutral friendly. The liquefied gas carrier **102** described herein contributes to a reduction in carbon footprint by improving efficiency based on being able to transport liquid gas and/or CO_2 during a return trip, rather than being empty.

[0028] The one or more dual-fluid storage tanks **104** contain or include an outer shell. An outer compartment is positioned within the outer shell. The outer compartment is configured to store the LNG. A bladder is positioned within the outer compartment. The bladder may be configured to expand when the CO_2 flows therein. The bladder may be present to reduce contamination between

Date Reçue/Date Received 2023-08-18

the CO_2 and the LNG. Insulation may be positioned between the outer shell and the outer compartment to provide temperature regulation from external heat sources to reduce boil off of the liquefied gas, such as LNG, stored or contained in the outer compartment and CO_2 stored or contained in the bladder.

[0029] In some embodiments, the outer compartment may be configured to store CO_2 and the bladder may be configured to store LNG or another liquid gas. In yet another embodiment, the outer compartment and the bladder may both be configured to store liquefied gas and CO_2, the liquefied gas and the CO_2 being stored in the outer compartment and bladder separately and at different times.

[0030] LNG may be transported at a temperature ranging from about -260 degrees Fahrenheit (ºF) to about -240 ºF. LNG may be transported at a pressure ranging from about 2 pounds per square inch gauge (psig) to about 5 psig. In certain embodiments, CO_2 may be stored as liquid CO_2. To maintain CO_2 in a liquid form, the temperature of CO_2 may be maintained below the critical point and above the triple point, as well as within a threshold pressure range, as will be understood by one skilled in the art. CO_2 may be transported at a temperature ranging from about -76 ºF and -87 ºF. CO_2 may be transported at a pressure ranging from about 85 psig to about 107 psig. LPG may be transported at a temperature ranging from about -54 ºF to about -22 ºF. LPG may be transported at atmospheric pressure. In some embodiments, the liquefied gas may be chilled to a temperature for the liquefied gas to remain a liquid gas. For dual transport of liquefied gas and CO_2, the CO_2 may be stored in the bladder (or in other embodiments, the outer compartment) with another fluid, such as nitrogen. In such embodiments, the concentration of CO_2 in relation to the other fluid may be less than 50 parts per million (ppm) to eliminate, substantially eliminate, and/or mitigate the risk of solidification.

[0031] Liquefied gas may be unloaded from the liquefied gas carrier **102** at a location and CO_2 may be loaded to the same liquefied gas carrier **102** at the same location. CO_2 may be unloaded from the liquefied gas carrier **102** at a location and liquefied gas may be loaded to the same liquefied gas carrier **102** at the same location.

[0032] Liquefied gas may be unloaded from the liquefied gas carrier **102** at a first location, the liquid gas carrier **102** may then travel to a second location to load CO_2, the CO_2 to be delivered to a third location or back to the first location. The liquefied gas carrier **102** may be loaded with

Date Reçue/Date Received 2023-08-18

liquefied gas to transport the liquefied gas to various locations in between delivery of CO_2 to a third location, a fourth location, and so on. CO_2 may be unloaded from the liquefied gas carrier **102** at a first location, the liquefied gas carrier **102** may then travel to a second location to receive or load liquefied gas for delivery of the liquefied gas to a third location or back to the first location. The liquefied gas carrier **102** may receive or load CO_2 for transport and transport the CO_2 to various locations in between delivery of the liquefied gas to a third location, a fourth location, and so on. In such embodiments, the liquefied gas carrier **102** makes use of the liquefied gas carrier's **102** entire travel route thereby increasing efficiency or carbon efficiency. Thus, the liquefied gas carrier **102**, based on such an increase in efficiency or carbon efficiency, decreases its carbon footprint by utilizing the capacity of the liquefied gas carrier **102**.

[0033] In embodiments, different types of bladders may be utilized, such as, for example, a low pressure bladder and/or an expanding bladder. A low pressure bladder may isolate different liquid gases. The dual-storage tank walls may be contacted with the CO_2 filled in the bladder. In such embodiments, the dual-storage tank may be designed or configured to hold fluid at a pressure of about 80 psig to about 107 psig.

[0034] The bladder may be constructed from polymers including elastomers or thermoplastic polymers. Such polymers may include FF202, EPDM, PEEK, Nylon, Neoprene, PTFE, Viton, EPR, and Buna N, among other similar polymers with similar properties, as will be understood by one skilled in the art. The bladder may be constructed of elastomer material such as perfluroelastomer material that can withstand the low-temperature and high pressure of the CO_2. Suitable elastomers may have reduced swelling properties under pressure. Such elastomers may also be able to withstand the lower temperatures at which liquefied gas may be stored, such as about -260 °F. The elastomers may also be able to withstand variation in temperatures of different liquefied gases. The bladder may be designed in a donut-shape, such that the bladder may circle around a pipe tower used to load and unload the liquid gases to and from, respectively, the outer compartment or bladder.

[0035] Insulation positioned between the outer shell and the outer compartment may be used to reduce boil-off. The insulation may be foam insulation, perlite insulation, fiber glass blanket insulation, or other types of insulation that may protect the liquefied gases from the dual-storage tank material.

Date Reçue/Date Received 2023-08-18

[0036] In some embodiments, the one or more dual-fluid storage tanks may have membranes, waffles, or baffles. The membranes, waffles, or baffles may be used to accommodate thermal expansion and contraction of the liquefied gases. The membranes, waffles, or baffles may be installed along the lower wall or portion of the outer shell of the dual-fluid storage tank. The membranes, waffles, or baffles may be fixedly or removably attached to the lower wall, top wall, left side wall, right side wall, or a portion of the outer shell of each of the one or more dual-fluid storage tanks. Such an attachment may be mechanical (for example, such as, via fasteners or welds). As the bladder expands, the bladder may press against the baffles. The baffles, in such examples, may stabilize the bladder when the bladder is partially and/or completely full. The membranes, waffles, or baffles may cover the full-length of each of the one or more dual-fluid storage tanks. The membranes, waffles, or baffles may be assembled in multiple portions to cover one or more lower wall, top wall, left side wall, or right side wall of the one or more dual-fluid vessel.

[0037] In some embodiments, the liquefied gas carrier **102** may have a water ballast system to balance the liquefied gas carrier's weight. The liquefied gas carrier **102** may load/de-ballast and unload/ballast simultaneously. In some embodiments, the liquefied gas carrier **102** may be designed to be ballast-free yet built to balance the liquefied gas carrier's **102** weight.

[0038] To maintain the liquid gas in a liquid state, the one or more dual-fluid storage tanks may be temperature-controlled. In certain embodiments, the one or more dual-fluid storage tanks may include and/or connect to one or more temperature-control apparatuses. The one or more temperature-control apparatuses may include temperature sensors, a refrigeration unit, a reliquification unit, the water ballast system, and/or other temperature-control apparatuses or devices as will be understood by one skilled in the art. If the liquid boils during transportation, as indicated by signals received by the one or more temperature control apparatuses from one or more temperature sensors positioned at varying locations within the one or more dual-fluid storage tanks, then the one or more dual-fluid storage tanks temperature may be controlled by the one or more temperature-control apparatuses. If the temperature rises (for example, above a selected threshold), as indicated by signals received by the one or more temperature control apparatuses from one or more temperature sensors positioned at varying locations within the one or more dual-fluid storage tanks, the one or more temperature-control apparatuses may signal to a control system and/or a refrigeration unit to cool the liquefied gas to maintain the state of the liquefied gases. If

Date Reçue/Date Received 2023-08-18

the temperature goes or falls below a minimum threshold or selected threshold, as indicated by signals received by the one or more temperature control apparatuses from one or more temperature sensors positioned at varying locations within the one or more dual-fluid storage tanks, then the one or more temperature-control apparatuses may signal to a control system and/or refrigeration unit to heat the liquid to maintain the state of the liquefied gases.

[0039] In some embodiments, multiple purging cycles may be used when the liquefied gas carrier **102** does not have or include a bladder or another means of isolation. In such embodiments, the outer compartment may contain or hold the liquid gas. Between unloading and loading of different liquid gases, the outer compartment may be purged for one or more cycles. The purging cycles may be used to prevent cross contamination between liquid gases. In such embodiments, one or more nitrogen or other gas tanks positioned on the liquefied gas carrier **102** and proximal to the one or more dual-fluid storage tanks may perform or may be utilized to purge the one or more dual-fluid storage tanks. Further the nitrogen or other gas tanks may store an amount of hydrogen and/or other gas or liquefied gas suitable for purging CO_2 and/or other liquefied gases, as will be understood by one skilled in the art.

[0040] To maintain the liquid gas in a liquid state, in addition to or rather than temperature control, the one or more dual-fluid storage tanks may be pressure-controlled. In certain embodiments, the one or more dual-fluid storage tanks may include and/or connect to one or more pressure-control apparatuses. The pressure-control apparatus may include pressure sensors, a ballast system, and/or other pressure-control apparatuses or devices. As the pressure changes and/or changes to a pressure outside of a selected threshold range, as indicated by signals received by the one or more pressure control apparatuses from one or more pressure sensors positioned at varying locations within the one or more dual-fluid storage tanks, then the pressure pressure-control apparatus may increase or decrease the pressure within the one or more dual storage tanks to drive the pressure to within the selected threshold range. In some embodiments, the pressure in the one or more dual storage tanks may be maintained within a pressure range by burning the liquid as fuel in the boilers of the liquefied gas carrier.

[0041] Separate pumps, piping and loading/unloading equipment may be used to reduce the risk of cross contamination. In addition to minimizing the risk of cross contamination, different pumps

Date Reçue/Date Received 2023-08-18

and piping may be utilized due to the differences in specific gravity of the liquid gases, for example, up to a 1.2 specific gravity for CO_2 and less than a 0.5 specific gravity for LNG.

[0042] The system **100** may include one or more pumps **118** that are configured to pump the liquefied gas from the one or more dual-fluid storage tanks **104**. System **100** also includes one or more articulated rigid loading arms **106A**, **106B**, **106C**, and **106D** positioned at a location and configured to connect to the liquefied gas carrier **102**, thereby connecting the liquefied gas carrier to the location or equipment (such as tanks or storage tanks) at the location. The one or more articulated rigid loading arms **106A**, **106B**, **106C**, and **106D** are configured to load and unload the LNG (or other liquefied gas) and/or CO_2 from the liquefied gas storage tanks **108A**, **108B**, **108C** or CO_2 storage tanks **110**, respectively. The one or more articulated rigid loading arms **106A**, **106B**, **106C**, and **106D** are connected to a vapor return line **116**. The vapor return line **116** is configured to return excess CO_2 to CO_2 storage tanks **110** positioned at the location. One or more articulated rigid loading arms **106A**, **106B**, **106C**, and **106D** are connected to a liquid return line **126** to transport liquefied gas, such as LNG, from the liquefied gas storage tanks **108** to the one or more dual-fluid storage tanks **104** or CO_2 from the CO_2 storage tanks **110** to the bladder in the one or more dual-fluid storage tanks **104**. The liquid return line **126** may also transport liquefied gas from one or more dual-fluid storage tanks **104** to the liquefied gas storage tanks **108** or the CO_2 from the bladder in the one or more dual-fluid storage tanks **104** to the CO_2 storage tanks **110**. A header **128** may be positioned to route the liquid return line **126** or the vapor return line **116** to a corresponding return tank.

[0043] A liquefaction unit **112** is positioned at the location and is configured to liquefy any gas or any liquefied gas that changes state to a gas that is delivered to the location. A dehydration unit **114** is also connected to the one or more articulated rigid loading arms. The dehydration unit **114** is configured to remove water from the liquid gases when the liquid gases are loaded onto the LNG carrier **102**.

[0044] As described herein, the one or more dual-fluid storage tanks **104** may operate about 80 pounds per square inch gauge (psig) to about 102 psig and about -260 degrees Fahrenheit.

[0045] The LNG carrier **102** may contain a first control room **124** that contains a first controller to control the unloading/loading operations of CO_2 and liquefied gas. The first controller may control temperature-control apparatuses, pressure-control apparatuses, flow meters, control valves,

Date Reçue/Date Received 2023-08-18

pumps, bladder dynamics, and nitrogen blankets used to stabilize the bladder. The first controller may also be in communication with a second controller located within a location control room **122** at the location to control unloading/loading operation of CO_2 and liquefied gas to/from CO_2 storage tanks and liquefied gas storage tanks. The first controller may be in signal communication with the second controller (for example, via a wireless connection). The system **100** may contain or include a supervisory controller that controls the first controller and/or the second controller and may communicate and/or control communication between the multiple controllers. In an embodiment, the first controller or the second controller may be a supervisory controller.

[0046] One or more valves (the one or more valves for example, positioned along the liquid return line **126**, within one or more articulated rigid loading arms **106A**, **106B**, **106C**, and **106D**, or elsewhere in the dual-fluid transport system **100**) may be controlled by the first controller and/or the second controller to control the flow of the liquefied gas, such as LNG and the CO_2. The second controller may send a signal to the one or more valves to open or close to direct flow of the liquefied gas and CO_2. The one or more valves may be used to direct the LNG flow from the one or more dual-fluid storage tanks **104** on the liquefied gas carrier **102** to the one or more liquefied gas storage tanks **108A**, **108B**, **108C**. The one or more valves also may be used to direct the CO_2 flow from the bladder to the one or more CO_2 storage tanks **110**. The one or more valves may direct LNG flow from the one or more liquefied gas storage tanks **108A**, **108B**, **108C** to the one or more liquefied gas storage tanks **108A**, **108B**, **108C**. The one or more valves may direct CO_2 from the one or more CO_2 storage tanks **110** to the bladder.

[0047] FIG. 2 is an illustrative diagram of a spherical liquefied gas carrier. In certain embodiments, a liquefied gas carrier **200** may be configured to transport liquefied gas and CO_2. The liquefied gas carrier **200** contains one or more dual-fluid storage tanks **202A**, **202B**, **202C**, and **202D** positioned on the liquefied gas carrier to transport LNG and/or CO_2. The one or more dual-fluid storage tanks **202A**, **202B**, **202C**, and **202D** may be positioned at a center-line of the liquefied gas carrier **200**.

[0048] The one or more dual-fluid storage tanks **202A**, **202B**, **202C**, and **202D** may be compatible with and/or configured to store liquefied gases having different boiling points, critical points, and volatility.

Date Reçue/Date Received 2023-08-18

[0049] The liquefied gas carrier **200** may contain or include a control room **204** having an unloading/loading controller to control the unloading/loading operations of CO_2 and liquefied gas. The unloading/loading controller may control temperature-control apparatuses, pressure-control apparatuses, flow meters, control valves, pumps, bladder dynamics, and nitrogen blankets used to stabilize the bladder. The controller also may be in communication with a land controller at the location to control unloading/loading operation of CO_2 and liquefied gas to/from CO_2 storage tanks and liquefied gas storage tanks. The unloading/loading controller may communicate wirelessly with the land controller. The system **200** may contain a supervisory controller that controls the unloading/loading controller and the land controller at the location and may control communication between the unloading/loading controller and the land controller. In an embodiment, the unloading/loading controller may be the supervisory controller or the land controller may be the supervisory controller.

[0050] The one or more dual-fluid storage tanks are illustrated in **FIGS. 3A-3C**. **FIG. 3A** is an illustrative diagram of a prismatic tank with a vertically expanding inner bladder attached therein. In the embodiment, the one or more dual-fluid storage tanks **300A** has an outer shell **302**. Each of the one or more dual-fluid storage tanks may have lower wall, top wall, left side wall, and right side wall. An outer compartment **306** is positioned within the outer shell **302**. The outer compartment **306** is configured to store the liquefied gas. A bladder **308** is positioned within the outer compartment **306**. The bladder **308** is configured to expand when the CO_2 the flows therein, thereby to reduce contamination between the CO_2 and the liquefied gas. The bladder may be used as a means of isolation to reduce the risk of cross contamination between liquid gases. Insulation **304** is positioned between the outer shell **302** and the outer compartment **306** to provide temperature regulation from external heat sources to reduce boil off of the liquefied gas when positioned in the outer compartment **306** and CO_2 when positioned in the bladder **308**. External heat sources may be the sun, reflected sunlight from planets and moons, heating by friction when traveling through an atmosphere or gas cloud, or other heat as will be understood by one skilled in the art.

[0051] **FIG. 3A** illustrates the bladder **308** at a bottom wall of the prismatic tank. The dual-fluid storage tank **300A** may have an outer shell and insulation **304** connected to the inner surface of the outer shell **302**. The bladder **308** may expand vertically within the outer compartment **306** when the CO_2 is positioned therein. The bladder **308** may expand horizontally within the outer

Date Reçue/Date Received 2023-08-18

compartment **306** when the CO_2 is positioned therein. Alternatively, the bladder **308** may be contractible when fluid is not positioned therein. The bladder **308** may connect, attach, or be mounted to an inner surface of each side wall. The mounts or plates attached to the inner surface of each side wall may be attached mechanically, such as via fasteners (for example, via welds, bolts). Other configurations of the dual-fluid storage tanks may include similar mountings, such as the dual-fluid storage tank illustrated in **FIG. 3B** (e.g., the bladder mount on the inner surface of the bottom wall of the dual-fluid vessel). The bladder may be expandable vertically within the outer compartment. **FIG. 3C** is an illustrative diagram of an expandable bladder **308** within a spherical tank **300C**. The bladder **308** may be mounted to each side wall to expand vertically or horizontally.

[0052] In some embodiments, as the bladder expands within the one or more dual storage tanks, the bladder may expand around a pipe tower within each of the one or more dual storage tanks. The pipe tower may be used to load or unload the liquid gas from each of the one of more dual storage tanks.

[0053] Given that the liquefied gas carrier may provide transportation of the one or more dual-fluid storage tanks over long distances in a body of water, stability of the bladder may prevent damage to the bladder or to the outer compartment. In some embodiments, the outer compartment is filled with nitrogen to stabilize the bladder. In some embodiments, the liquefied gas carrier may contain onboard nitrogen vessels to equalize the pressure between the bladder and the outer compartment. One or more pressure sensors may be positioned within the bladder and/or outer compartment. The one or more pressure sensors may sense, measure, or determine the pressure within the bladder and/or outer compartment and provide such measurements to a controller or control system. The controller or control system may, in response to a pressure that is outside of a threshold range, release nitrogen into the outer compartment to equalize pressure.

[0054] **FIG. 4A-4H** is an illustrative diagram of different phases of unloading/loading liquefied gases and CO_2 within one or more dual-fluid storage tanks. As illustrated in **FIG. 4A**, a dual-fluid storage tank **402** may be filled with liquefied gas in the outer compartment **406**. The bladder **404** may be empty. In **FIG. 4B**, the amount of liquefied gas in the outer compartment 406 is less than the amount of liquefied gas as illustrated in **FIG. 4A**. As the liquefied gas is continuously removed from the outer compartment **404**, the outer compartment is emptied, as illustrated in **FIG. 4C**.

Date Reçue/Date Received 2023-08-18

With an empty outer compartment **404**, the bladder **404** may be filled with CO_2, as illustrated in **FIG. 4D**. In **FIG. 4E** and **FIG. 4F**, CO_2 is continuously added into the bladder **404**. In **FIG. 4G**, the bladder **404** expands to fill the entire outer compartment **406**. In **FIG. 4H**, a blanket of nitrogen is added to the outer compartment **406** to stabilize the bladder **404** during transport.

[0055] **FIG. 5** is an illustrative diagram of a spherical liquefied gas carrier stationed at a terminal. The one or more dual-fluid storage tanks **504A**, **504B, 504C, and 504D** may include one or more of spherical tanks. In the embodiment, CO_2 may be liquid CO_2. In other embodiments, the one or more dual-fluid storage tanks **504A**, **504B, 504C, and 504D** contain membranes, waffles, or baffles. The membranes, waffles, or baffles may act as a secondary containment system, in the event of the dual-fluid storage tank leakage. The membrane, waffle, or baffle used in the dual-fluid storage tank may depend on the tank shape and the type of liquid gas carried in the one or more dual-fluid storage tanks. In some embodiments, the membranes, waffles, or baffles may partially-cover the length of each of the one or more dual-fluid tanks. In other embodiments, the membranes, waffles, or baffles may cover the full-length of each of the one or more dual-fluid tanks.

[0056] The system **500** may include one or more pumps **518** that are configured to pump the liquefied gas from the one or more dual-fluid storage tanks **504A**, **504B**, **504C**, and **504D**. System **500** further includes one or more articulated rigid loading arms **506A**, **506B**, **506C**, and **506D** positioned at a location to connect the liquefied gas carrier **502** to the location. The one or more articulated rigid loading arms **506A**, **506B**, **506C**, and **506D** are configured to load and unload the liquefied gas and/or CO_2 from the liquefied gas storage tanks or CO_2 storage tanks, respectively. The vapor return line **516** is connected to the one or more articulated rigid loading arms **506A**, **506B**, **506C**, and **506D** and is configured to return excess CO_2 to CO_2 storage tanks **510** positioned at the location. One or more articulated rigid loading arms **506A**, **506B**, **506C**, and **506D** are connected to a liquid return line **526** to transport liquefied gas from the liquefied gas storage tanks **508** to the one or more dual-fluid storage tanks **504A**, **504B**, **504C**, and **504D** or CO_2 from the CO_2 storage tanks **510** to the bladder in the one or more dual-fluid storage tanks **504A**, **504B**, **504C**, and **504D**. The liquid return line **526** may also transport liquefied gas from one or more dual-fluid storage tanks **504A**, **504B**, **504C**, and **504D** to the liquefied gas storage tanks **508** or the CO2 from the bladder in the one or more dual-fluid storage tanks **504A**, **504B**, **504C**, and **504D** to the CO_2 storage tanks **510**.

Date Reçue/Date Received 2023-08-18

[0057] A liquefaction unit **512** is positioned at the location and is configured to liquefy any gas or any liquefied gas that changes state to a gas that is delivered to the location. A dehydration unit **514** is also connected to the one or more articulated rigid loading arms. The dehydration unit **514** may be configured to remove water from the liquid gases when the liquid gases are loaded onto the liquefied gas carrier **502**.

[0058] As described herein, the one or more dual-fluid storage tanks **504A**, **504B**, **504C**, and **504D** may operate from about 80 pounds per square inch gauge (psig) to about 102 PSI and at a minimum temperature of about -260 degrees Fahrenheit.

[0059] The liquefied gas carrier **504** may contain a first control room **524** having a first controller to control the unloading/loading operations of CO_2 and liquefied gas. The first controller **524** may control temperature-control apparatuses, pressure-control apparatuses, flow meters, control valves, pumps, bladder dynamics, and nitrogen blankets used to stabilize the bladder. The first controller may also be in communication with a second controller located within a location control room **522** at the location to control unloading/loading operation of CO_2 and liquefied gas to/from CO_2 storage tanks and liquefied gas storage tanks, respectively. The first controller may communicate wirelessly with the second controller. The second controller may send a signal to the one or more valves to open or close to direct flow of the liquefied gas and CO_2. The system **500** may contain a supervisory controller that controls the first controller and the second controller to communicate between the multiple controllers. The first controller or the second controller may be a supervisory controller.

[0060] A method of unloading/loading liquefied gas and carbon dioxide (CO_2) at a location may include aligning one or more articulated rigid loading arms positioned at a location with one or more dual-fluid storage tanks positioned on a liquefied gas carrier. The one or more dual-fluid storage tanks have an outer compartment configured to store liquefied gas and a bladder connected to a wall within the outer compartment configured to store CO_2. The CO_2 may include liquid CO_2. The bladder may include an expandable bladder that expands as the CO_2 flows therein.

[0061] The method further includes connecting each of the one or more articulated rigid loading arms, via a first controller, to the outer compartment or the bladder of each of the one or more dual-fluid storage tanks. The first controller may be located on the liquefied gas carrier.

Date Reçue/Date Received 2023-08-18

[0062] If the outer compartment contains liquefied gas, in response to reception of a first liquefied gas pump operation signal from the first controller and a second liquefied gas pump operation signal from a second controller, the method may further include pumping a first liquefied gas from the outer compartment to one or more liquefied gas storage tanks and of (a) a second liquefied gas from one or more liquefied gas storage tanks to the outer compartment or (b) CO_2 from one or more CO_2 storage tanks to the bladder. The second controller may be located at the location.

[0063] Alternatively, if the bladder contains CO_2, in response to reception of a first CO_2 signal from the first controller and a signal from a second CO_2 signal from the second controller, the method may further include pumping CO_2 from the bladder to one or more CO_2 storage tanks at the location and the second liquefied gas from one or more liquefied gas storage tanks to the outer compartment.

[0064] In some embodiments, the method further includes directing the CO_2 from the one or more CO_2 storage tanks via the first controller and the second controller to a dehydration unit positioned at the location. The method may also include dehydrating the CO_2 by operation of the dehydration unit via the second controller before loading the CO_2 on the liquefied gas carrier.

[0065] FIG. 6 is a simplified block diagram for unloading/ loading liquefied gas and carbon dioxide in a liquefied gas carrier. In certain embodiments, the method includes the step **602** of stationing a liquefied gas carrier at a location. As described herein, the liquefied gas carrier contains one or more dual-fluid storage tanks positioned on the liquefied gas carrier to transport liquid gas that includes liquefied gas and/or CO_2. The one or more dual-fluid storage tanks contain (a) an outer shell, (b) an outer compartment positioned within the outer shell configured to store the liquefied gas, (c) a bladder positioned within the outer compartment connected to a wall within the outer compartment and is configured to store the CO_2 , and (d) insulation positioned between the outer shell and the outer compartment to provide temperature regulation for the liquefied gas when positioned in the outer compartment and CO_2 in the bladder.

[0066] The method also includes the step **604** of aligning one or more articulated rigid loading arms positioned at the location with the one or more dual-fluid storage tanks. The method further includes the step **606** of connecting each of the one or more articulated rigid loading arms to the outer compartment or the bladder of each of the one or more dual-fluid storage tanks, as understood by those skilled in the art. The method also includes the step **608** of pumping the liquid gas from

Date Reçue/Date Received 2023-08-18

the outer compartment or the CO_2 from the bladder to one or more discharge storage tanks at the location, as understood by those skilled in the art. The method further includes the step **610** of pumping the liquid gas and/or CO_2 from one or more storage tanks to the outer compartment or the bladder. The method also includes the step **612** of disconnecting each of the one or more articulated rigid loading arms from the outer compartment or the bladder of each of the one or more dual-fluid storage tanks.

[0067] The method may further include the step of directing the fluid, CO_2, from the one or more CO_2 storage tanks to a dehydration unit positioned at the location. The method also includes the step of dehydrating the CO_2 by operation of the dehydration unit before loading the CO_2 on the liquefied gas carrier.

[0068] FIG. 7A is a simplified diagram implemented in a liquefied gas carrier controller, for controlling unloading and onloading operations from the liquefied gas carrier. The liquefied gas carrier may be an LNG carrier, an LPG carrier, or another type of liquefied gas carrier. Embodiments include a controller for a liquefied gas carrier for transporting liquefied gas and CO_2. The controller may include a processor **704**, a memory **706**, and unloading or onloading operations instructions **708**. The liquefied gas carrier controller **702** may include memory **706** and one or more processors **704**. The memory **706** may store instructions executable by one or more processors **704**. In an example, the memory **706** may be a non-transitory machine-readable storage medium. As used herein, a "machine-readable storage medium" may be any electronic, magnetic, optical, or other physical storage apparatus or cyber-physical separation storage to contain or store information such as executable instructions, data, and the like. For example, any machine-readable storage medium described herein may be any of random access memory (RAM), volatile memory, non-volatile memory, flash memory, a storage drive (e.g., hard drive), a solid-state drive, any type of storage disc, and the like, or a combination thereof. As noted, the memory **706** may store or include instructions executable by the processor **704**. As used herein, a "processor" may include, for example, one processor or multiple processors included in a single device or distributed across multiple computing devices. The processor **704** may be at least one of a central processing unit (CPU), a semiconductor-based microprocessor, a graphics processing unit (GPU), a field-programmable gate array (FPGA) to retrieve and execute instructions, a real-time processor (RTP), other electronic circuitry suitable for the retrieval and execution instructions stored on a machine-readable storage medium, or a combination thereof.

Date Reçue/Date Received 2023-08-18

[0069] As used herein, "signal communication" refers to electric communication such as hard wiring two components together or wireless communication, as understood by those skilled in the art. For example, wireless communication may be Wi-Fi®, Bluetooth®, ZigBee, or forms of near field communications. In addition, signal communication may include one or more intermediate controllers or relays disposed between elements in signal communication.

[0070] The liquefied gas carrier controller **702** may be in signal communication with various other controllers throughout or external to the liquid gas carrier. The liquefied gas carrier controller **702** may be considered a supervisory controller. In another embodiment, a supervisory controller may include the functionality of controller **732**, as shown in **FIG 7B**.

[0071] As noted, the memory **706** may include instructions for unloading/onloading operations **708**. The pressure sensors may send a signal to the liquefied gas carrier controller **702** indicating pressure or another characteristic (for example, temperature, etc.) within a bladder or outer compartment. The liquefied gas carrier controller **702** may perform, execute, or adjust execution of the unloading/onloading operations **708** based on such indications. The unloading/onloading operations **708** may include instructions may use characteristics or signals provided relating to temperature-control apparatuses **710**, pressure-control apparatuses **712**, first meter **714**, second meter **716**, first control valve **718**, and second control valve **720**.

[0072] The liquefied gas carrier controller **702** may include a first input/output in signal communication with one or more temperature-control apparatuses **710**. The one or more temperature-control apparatuses **710** may be positioned within an outer compartment of each of one or more dual-fluid storage tanks on a liquefied gas carrier. The one or more temperature-control apparatuses **710** may also be positioned within a bladder being positioned within the outer compartment. The liquefied gas carrier controller is configured to obtain a first temperature of a liquefied gas contained within the outer compartment and a second temperature of CO_2 contained within the bladder during unloading operations, unloading operations, and transport of the liquefied gas and CO_2.

[0073] The liquefied gas carrier controller **702** may also include a second input/output in signal communication with one or more pressure-control apparatuses **712**. The one or more pressure-control apparatuses **712** may be positioned within the outer compartment of each of one or more dual-fluid storage tanks and the bladder. The liquefied gas carrier controller **702** is configured to

Date Reçue/Date Received 2023-08-18

obtain a first pressure of the liquefied gas contained within the outer compartment and a second pressure of CO_2 contained within the bladder during the unloading operations, the unloading operations, and the transport of the liquefied gas and CO_2.

[0074] The liquefied gas carrier controller **702** may include instructions to maintain a specified temperature range and/or pressure range within the outer compartment and/or the bladder during transit. Such instructions may use the same or similar components used for unloading/onloading operations. Upon execution of the instructions, during transit, the liquefied gas carrier controller **702** may determine the first temperature of the outer compartment and/or the second temperature of the bladder (for example, via sensors and/or other temperature sensors positioned throughout the one or more dual-fluid storage tanks), the first pressure of the outer compartment and/or the second pressure of the bladder (for example, via pressure sensors), a first fluid level of the outer compartment (for example, via sensors and/or other temperature sensors positioned throughout the one or more dual-fluid storage tanks), and/or a second fluid level of the bladder (for example, via sensors and/or other temperature sensors positioned throughout the one or more dual-fluid storage tanks). The liquefied gas carrier controller **702** may include or store (for example, in memory **706**) various pressure ranges for different fluids. After an unloading/onloading operation, the liquefied gas carrier controller **702** may receive an indication on the type of liquefied gas currently contained in the one or more dual-fluid storage tanks. The liquefied gas carrier controller **702** may determine the pressure and/or temperature ranges based on the type of liquefied gas and how much of that type of liquefied gas is in the outer compartments. The liquefied gas carrier controller **702** may monitor the current temperature and/or pressure continuously or substantially continuously. If the current temperature and/or pressure is less than the temperature and/or pressure range, the liquefied gas carrier controller **702** may cause a pump or compressor attached to or proximate to the dual-fluid vessel to activate and operate until pressure is within the range. If the current temperature and/or pressure is greater than the temperature and/or pressure range, the liquefied gas carrier controller **702** may cause a relief valve to actuate to decrease pressure within the dual-fluid vessel. The liquefied gas carrier controller **702** may also control a refrigeration unit to maintain the temperature range.

[0075] The liquefied gas carrier controller **702** may further include a third input/output in signal communication with a first flow meter **714** positioned at a first inlet of the outer compartment and a second flow **716** meter positioned at a second inlet of the bladder. The liquefied gas carrier

Date Reçue/Date Received 2023-08-18

controller **702** is configured to measure a first flow rate of the liquefied gas and a second flow rate of the CO_2.

[0076] The liquefied gas carrier controller **702** may also include a fourth input/output in signal communication with a first control valve **718**. The first control valve **718** designed to adjust flow of the liquefied gas via one or more unloading/loading pumps positioned on the liquefied gas carrier thereby modifying the first flow rate of the liquefied gas and a second control valve **720**. The second control valve **720** designed to adjust flow of the CO_2 via the one or more unloading/loading pumps thereby modifying the second flow rate.

[0077] The liquefied gas carrier controller **702** is configured to, after initiation of the unloading operations or the loading operations, determine whether the first flow rate or the second flow rate is to be modified based on an outer compartment temperature, an outer compartment pressure, a bladder pressure, or a bladder temperature. In response to a determination that the first flow rate is to be modified, the liquefied gas carrier controller **702** may adjust a position of the first flow control valve that adjusts flow of the liquefied gas, thereby modifying the first flow rate. The liquefied gas carrier controller **702** may also in response to a determination that the second flow rate is to be modified, adjust a position of the second flow control valve that adjusts flow of the CO_2, thereby modifying the second flow rate.

[0078] FIG. 7B is a simplified diagram implemented in a location controller, for controlling unloading and onloading operations at the location. The location controller **732** may include a processor **734**, a memory **736**, and unloading or onloading operations instructions **708**. The location controller **732** may include memory **736** and one or more processors **704**. The memory **706** may store instructions executable by one or more processors **734**. In an example, the memory **736** may be a non-transitory machine-readable storage medium. As noted, the memory **736** may store or include instructions executable by the processor **734**. The processor **734** may be at least one of a CPU, a semiconductor-based microprocessor, a GPU, a FPGA to retrieve and execute instructions, a RTP, other electronic circuitry suitable for the retrieval and execution instructions stored on a machine-readable storage medium, or a combination thereof.

[0079] The location controller **732** may be in signal communication with various other controllers throughout the location and internal to the liquid gas carrier. The location controller **732** may be

Date Reçue/Date Received 2023-08-18

considered a supervisory controller. In another embodiment, a supervisory controller may include the functionality of the liquefied gas carrier controller **702** and/or the location controller **732**.

[0080] As noted, the memory **736** may include instructions for unloading/onloading operations **738**. The pressure sensors may send a signal to the location controller **732** indicating pressure or another characteristic (for example, temperature or flow rate) within a bladder or outer compartment. The location controller **732** may perform, execute, or adjust execution of the unloading/onloading operations **708** based on such indications. The unloading/onloading operations **708** may include instructions may use characteristics or signals provided relating to temperature-control apparatuses **740**, pressure-control apparatuses **742**, third meter **744**, fourth meter **746**, third control valve **748**, fourth control valve **750**, and rigid loading arms **752**.

[0081] The location controller **732** may include a first input/output in signal communication with one or more temperature-control apparatuses **740**. The one or more temperature-control apparatuses **740** may be positioned within the liquefied gas storage tanks at the location. The one or more temperature-control apparatuses **740** may also be positioned within the CO_2 storage tanks at the location. The location controller **732** is configured to obtain a first temperature of a liquefied gas contained within the liquefied gas storage tanks and a second temperature of CO_2 contained within the CO_2 storage tanks at the location during unloading operations and unloading operations of the liquefied gas and CO_2.

[0082] The location controller **732** may also include a second input/output in signal communication with one or more pressure-control apparatuses **742**. The one or more pressure-control apparatuses **742** may be positioned within the liquefied gas storage tanks and the CO_2 storage tanks at the location. The location controller **732** is configured to obtain a third pressure of the liquefied gas at the location and a fourth pressure of CO_2 at the location during the unloading operations and the loading operations of the liquefied gas and CO_2.

[0083] The location controller **732** may include instructions to maintain a specified temperature range and/or pressure range within the liquefied gas storage tanks and the CO_2 storage tanks. Such instructions may use the same or similar components used for unloading/onloading operations. Upon execution of the instructions, the location controller **732** may determine the third temperature of the liquefied gas storage tanks and/or the fourth temperature of the CO_2 storage tanks (for example, via sensors and/or other temperature sensors positioned throughout the liquefied gas

Date Reçue/Date Received 2023-08-18

storage tanks and the CO_2 storage tanks), the third pressure of the liquefied gas storage tanks and/or the fourth pressure of the CO_2 storage tanks (for example, via pressure sensors), a third fluid level of the liquefied gas storage tanks (e.g., via sensors for example and/or other temperature sensors positioned throughout the liquefied gas storage tanks), and/or a fourth fluid level of the CO_2 storage tanks (for example, via sensors and/or other temperature sensors positioned throughout the CO_2 storage tanks). The location controller **732** may include or store (for example, in memory **736**) various pressure ranges for different fluids. After an unloading/onloading operation, the location controller **732** may receive an indication on the type of liquefied gas currently contained in the liquefied gas storage tanks or CO_2 storage tanks. The location controller **732** may determine the pressure and/or temperature ranges based on the type of liquefied gas and how much of that type of liquefied gas is in the liquefied gas storage tanks or CO_2 storage tanks. The location controller **732** may monitor the current temperature and/or pressure continuously or substantially continuously. If the current temperature and/or pressure is less than the temperature and/or pressure range, the location controller **732** may cause a pump or compressor attached to or proximate to the liquefied gas storage tanks or CO_2 storage tanks to activate and operate until pressure is within the range. If the current temperature and/or pressure is greater than the temperature and/or pressure range, the location controller **732** may cause a relief valve to actuate to decrease pressure within the liquefied gas storage tanks or CO_2 storage tanks. The location controller **732** may also control a refrigeration unit to maintain the temperature range.

[0084] The location controller **732** may further include a third input/output in signal communication with a third flow meter **744** positioned at an inlet of the liquefied gas storage tanks and a fourth flow **746** meter positioned at an inlet of the CO_2 storage tanks. The location controller **732** is configured to measure a third flow rate of the liquefied gas and a fourth flow rate of the CO_2.

[0085] The location controller **732** may also include a fourth input/output in signal communication with a third control valve **748**. The third control valve **748** is designed to adjust flow of the liquefied gas via one or more liquefied gas unloading/loading pumps positioned at the location thereby modifying the third flow rate of the liquefied gas. The fourth control valve **750** designed to adjust flow of the CO_2 via the one or more CO_2 unloading/loading pumps thereby modifying the fourth flow rate.

Date Reçue/Date Received 2023-08-18

[0086] The location controller **732** may also include a fifth input/output in signal communication with the one or more articulated rigid loading arms **752**. The one or more articulated rigid loading arms **752** connects the dual-fluid storage tank on the liquefied gas carrier to the location. At the location, the one or more articulated loading arms **752** connect to a conduit that may supply the liquefied gas to the liquefied gas storage tanks or the CO_2 storage tanks. The conduit may be a hose, a pipe, or another form of transporting liquid gases.

[0087] The location controller **732** is configured to, after initiation of the unloading operations or the loading operations, determine whether the third flow rate or the fourth flow rate is to be modified based on an liquefied gas storage tank temperature, a liquefied gas storage tank pressure, a CO_2 storage tank pressure, or a CO_2 storage tank temperature. In response to a determination that the third flow rate is to be modified, the location controller **732** may adjust a position of the third flow control valve that adjusts flow of the liquefied gas, thereby modifying the third flow rate. The location controller **732** may also in response to a determination that the second flow rate is to be modified, adjust a position of the second flow control valve that adjusts flow of the CO_2, thereby modifying the second flow rate.

[0088] Unloading operations may include controlling the flow from the outer compartment and bladder and shutting off pumps when pressure is outside of safe operating conditions. Onloading operations may include controlling flow from the CO_2 storage tanks and liquefied gas storage tanks at a location and shutting off pumps when pressure is outside of safe operating conditions. In certain embodiments, the location controller **732** may control the operation of a liquefied gas pump used to load/unload liquefied gas and a CO_2 pump used to load/unload CO_2. In certain embodiments, the liquefied gas carrier controller **702** may control nitrogen operations from nearby nitrogen storage vessels or on-board nitrogen tanks. The liquefied gas carrier controller **702** may determine, based on signals from the pressure sensors, when nitrogen may be added to the outer compartment.

[0089] FIG. 7C is a simplified diagram of the interaction between the liquefied gas carrier controller **702** and the location controller **732**. The liquefied gas carrier controller **702** and the location controller **732** may communicate to assist in loading operations and unloading operations. The location controller **732** may be the supervisory controller. The supervisory controller may

Date Reçue/Date Received 2023-08-18

receive signals from the liquefied gas carrier controller **702** to coordinate the loading operations and unloading operations.

[0090] **FIG. 8** is a simplified diagram implemented in a controller, for controlling unloading and onloading operations. In certain embodiments, the method includes the step **802** of stationing an LNG carrier at a location. The method further includes the step **804** of aligning the articulated rigid arms with the dual-fluid storage tanks. The method also includes the step **806** of connecting the articulated rigid loading arms to the outer compartment or bladder, based on the content that will be loaded and/or unloaded. The method further includes the step **808** of determining the pressure and temperature of the dual-fluid storage tanks (for example, via one or more sensors positioned therein and in signal communication with the controller).

[0091] The controller will then determine whether the temperature of the content is within a threshold range at step **810**. The threshold range may be determined by or preselected based on the type of liquefied gas within the dual-fluid storage tank. If it is determined that the temperature of the content is not within the threshold range, the method further includes the step **812** of adjusting the temperature of the content. The temperature of content may be adjusted using refrigeration units or other apparatuses known by those skilled in the art. The temperature may be adjusted until the temperature of the content is within the threshold range for the content.

[0092] If the temperature of the content is within the threshold range, the controller then determines at step **814** whether the outer compartment contains liquefied gas. If the outer compartment does contain liquefied gas, it is then determined, at step **816**, whether a first liquefied gas pump operation signal and a second liquefied gas pump operation signal received. The first liquefied gas pump operation signal may be received from the first liquefied gas pump located on the LNG carrier. The second liquefied gas pump operation signal may be received from the second liquefied gas pump located at the location.

[0093] If the first liquefied gas pump operation signal and the second liquefied gas pump operation signal is not received, the method further includes the step **820** of verifying whether the loading or unloading process is ready. Verifying that the loading or unloading process is ready may include verifying that both the first liquefied gas pump and the second liquefied gas pump is on and operational, verifying that the conduits that may be used to transport the liquefied gases are

Date Reçue/Date Received 2023-08-18

connected, and other operational checks known to those skilled in the art. Once the verification process is complete, the controller then repeats step **816**.

[0094] If it determined that the first liquefied gas pump operation signal and the second liquefied gas pump operation signal is received, the method further includes the step **824** of pumping liquefied gas from the outer compartment to a liquefied gas storage tank or from the liquefied gas storage tank to the outer compartment depending on whether the liquefied gas is being loaded or unloaded. The method also includes the step **826** of determining the pressure and temperature of the liquefied gas storage tank and the outer compartment or the CO2 storage tank and the bladder depending on which liquefied gas is being loaded or unloaded. The method further includes the step **828** of disconnecting the articulated rigid arms from the outer compartment or the bladder.

[0095] If the outer compartment does not contain liquefied gas, the controller then determines at step **818** whether a first CO_2 signal and a second CO_2 signal was received. The first CO_2 signal may be received from the first CO_2 pump located on the LNG carrier. The second CO_2 signal may be received from the second CO_2 pump located at the location. If it is determined that the first CO_2 signal and the second CO_2 signal is not received, the method further includes the step **820** of verifying whether the loading or unloading process is ready. Verifying that the loading or unloading process is ready may include verifying that both the first CO_2 pump and the second CO_2 pump is on and operational, verifying that the conduits that may be used to transport the CO_2 are connected, and other operational checks known to those skilled in the art. Once the verification process is complete, the controller then repeats step **818**.

[0096] If it is determined that the first CO_2 signal and the second CO_2 signal is received, the method further includes the step **822** of pumping CO_2 from the bladder to the CO_2 storage tank or from the CO_2 storage tank to the bladder. The method also includes the step **826** of determining the pressure and temperature of the liquefied gas storage tank and the outer compartment or the CO2 storage tank and the bladder depending on which liquefied gas is being loaded or unloaded. The method further includes the step **828** of disconnecting the articulated rigid arms from the outer compartment or the bladder.

[0097] In the drawings and specification, several embodiments of systems and methods to provide scalable greenhouse gas capture have been disclosed, and although specific terms are employed, the terms are used in a descriptive sense only and not for purposes of limitation. Embodiments of

Date Reçue/Date Received 2023-08-18

systems and methods have been described in considerable detail with specific reference to the illustrated embodiments. However, it will be apparent that various modifications and changes may be made within the spirit and scope of the embodiments of systems and methods as described in the foregoing specification, and such modifications and changes are to be considered equivalents and part of this disclosure.

Date Reçue/Date Received 2023-08-18

CLAIMS

1. A liquefied gas carrier to transport liquefied gas and carbon dioxide (CO_2), the liquefied gas carrier comprising:

   one or more dual-fluid storage tanks positioned on the liquefied gas carrier to transport liquefied gas or CO_2, the one or more dual-fluid storage tanks having:

   an outer shell;

   an outer compartment positioned within the outer shell and configured to store the liquefied gas;

   a bladder positioned within the outer compartment and configured to expand when the CO_2 flows therein, thereby to reduce contamination between the CO_2 and the liquefied gas; and

   insulation positioned between the outer shell and the outer compartment to provide temperature regulation from external heat sources to reduce boil off of the (a) liquefied gas when positioned in the outer compartment and (b) CO_2 in the bladder.

2. The liquefied gas carrier of claim 1, wherein a pressure and temperature rating for the one or more dual-fluid storage tanks comprises a maximum pressure of about 80 pounds per square inch gauge (psig) to about 102 pounds psig and a minimum temperature of about -260 degrees Fahrenheit minimum temperature.

3. The liquefied gas carrier of claim 1, wherein the one or more dual-fluid storage tanks comprises one or more of spherical tanks, refrigerated tanks, prismatic tanks, cylindrical tanks, or bilobe tanks.

4. The liquefied gas carrier of claim 1, wherein the one or more dual-fluid storage tanks include one or more (a) temperature-control apparatuses to control a temperature within the one or more dual-fluid storage tanks or (b) pressure-control apparatuses to control a pressure within the one or more dual-fluid storage tanks.

5. The liquefied gas carrier of claim 1, further comprising a nitrogen tank positioned proximal and connected to one of the one or more dual-fluid storage tanks and wherein the nitrogen tank is configured to, if the bladder is partially or substantially empty, fill the outer compartment with nitrogen to stabilize the bladder.

Date Reçue/Date Received 2023-08-18

6. The liquefied gas carrier of claim 1, wherein the one or more dual-fluid storage tanks further include one or more membranes, waffles, or baffles positioned within the outer compartment of each of the one or more dual-fluid storage tanks.
7. A dual-fluid transport system for transporting liquefied gas and carbon dioxide (CO_2), the dual-fluid transport system comprising:

a liquefied gas carrier configured to transport liquefied gas and CO_2, the liquefied gas carrier comprising:

one or more dual-fluid storage tanks positioned on the liquefied gas carrier to transport the liquefied gas or the CO_2, the one or more dual-fluid storage tanks having:

an outer shell;

an outer compartment positioned within the outer shell, the outer compartment configured to store the liquefied gas;

a bladder positioned within the outer compartment and configured to expand when the CO_2 flows therein, thereby to reduce contamination between the CO_2 and the liquefied gas;

insulation positioned between the outer shell and the outer compartment to provide temperature regulation from external heat sources to reduce boil off of one or more of (a) the liquefied gas when positioned in the outer compartment and (b) the CO_2 when positioned in the bladder;

one or more pumps configured to pump the liquefied gas and CO_2 from the one or more dual-fluid storage tanks;

a first controller positioned within a first control room to control unloading/loading operations of CO_2 from the bladder and liquefied gas from the outer compartment;

one or more articulated rigid loading arms positioned at a location and to connect the liquefied gas carrier to the location and configured to load and unload the liquefied gas and CO_2;

a vapor return line connected to the one or more articulated rigid loading arms and configured to return excess vapor from the liquefied gas to the location;

Date Reçue/Date Received 2023-08-18

one or more liquefied gas storage tanks configured to store liquefied gas and one or more CO_2 storage tanks configured to store CO_2;

a dehydration unit (a) positioned between the one or more articulated rigid loading arms and the one or more liquefied gas storage tanks and (b) configured to remove water from the CO_2 when the CO_2 is loaded onto the liquefied gas carrier; and

a second controller positioned within a location control room at the location and to control unloading/loading operation of CO_2 and liquefied gas to/from CO_2 storage tanks and liquefied gas storage tanks.

8. The dual-fluid transport system of claim 7, wherein the one or more dual-fluid storage tanks comprises a maximum pressure of about 80 pounds per square inch gauge (psig) to about 102 psig and a minimum temperature of about -260 degrees Fahrenheit.
9. The dual-fluid transport system of claim 7, wherein the one or more dual-fluid storage tanks comprises one or more of spherical tanks, refrigerated tanks, prismatic tanks, cylindrical tanks, or bilobe tanks.
10. The dual-fluid transport system of claim 7, wherein the one or more dual-fluid storage tanks include one or more of (a) temperature-control apparatuses to control a temperature within the one or more dual-fluid storage tanks or (b) pressure-control apparatuses to control a pressure within the one or more dual-fluid storage tanks.
11. The dual-fluid transport system of claim 7, further comprising a nitrogen tank positioned proximal and connected to one of the one or more dual-fluid storage tanks and wherein the nitrogen tank is configured to, if the bladder is partially or substantially empty, fill the outer compartment with nitrogen to stabilize the bladder.
12. The dual-fluid transport system of claim 7, wherein the one or more dual-fluid storage tanks includes one or more membranes, waffles, or baffles positioned within each of the one or more dual-fluid storage tanks.
13. The dual-fluid transport system of claim 7, wherein the one or more dual-fluid storage tanks further comprises one or more sensors, the one or more sensors to determine a temperature or a pressure of the liquefied gas and the CO_2.
14. The dual-fluid transport system of claim 7, further comprising a liquefaction unit positioned at the location to transfer the CO_2 to the liquefied gas carrier.

Date Reçue/Date Received 2023-08-18

15. The dual-fluid transport system of claim 7, further comprising one or more valves positioned between the one or more articulated rigid loading arms and the one or more liquefied gas storage tanks and one or more CO2 storage tanks, and wherein the one or more valves are controlled by the first controller and/or the second controller thereby to control the flow of the liquefied gas and the CO_2.
16. A method of unloading/loading liquefied gas and carbon dioxide (CO_2) at a location, the method comprising:

aligning one or more articulated rigid loading arms positioned at a location with one or more dual-fluid storage tanks positioned on a liquefied gas carrier, the one or more dual-fluid storage tanks including an outer compartment configured to store liquefied gas and a bladder connected to a wall within the outer compartment configured to store CO_2;

connecting each of the one or more articulated rigid loading arms, via a first controller, to the outer compartment or the bladder of each of the one or more dual-fluid storage tanks; and

if the outer compartment contains liquefied gas:

in response to reception of a first liquefied gas pump operation signal from the first controller and a second liquefied gas pump operation signal from a second controller, pumping a first liquefied gas from the outer compartment to one or more liquefied gas storage tanks and one of (a) a second liquefied gas from one or more liquefied gas storage tanks to the outer compartment or (b) CO_2 from one or more CO_2 storage tanks to the bladder; or

if the bladder contains CO_2:

in response to reception of a first CO_2 signal from the first controller and a signal from a second CO2 signal from the second controller, pumping CO_2 from the bladder to one or more CO_2 storage tanks at the location and the second liquefied gas from one or more liquefied gas storage tanks to the outer compartment.

17. The method of claim 16, wherein the CO_2 comprises liquid CO_2.
18. The method of claim 16, wherein the bladder comprises an expandable bladder that expands as the CO_2 flows therein.

Date Reçue/Date Received 2023-08-18

19. The method of claim 16, further comprising:

directing the CO_2 from the one or more CO_2 storage tanks via the first controller and the second controller to a dehydration unit positioned at the location; and

dehydrating the CO_2 by operation of the dehydration unit via the second controller before loading the CO_2 on the liquefied gas carrier.

20. The method of claim 16, wherein the first controller is located on the liquefied gas carrier and wherein the second controller is located at the location.

21. A controller for a liquefied gas carrier for transporting liquefied gas and carbon dioxide (CO_2), the controller comprising:

a first input/output in signal communication with one or more temperature-control apparatuses positioned within an outer compartment of each of one or more dual-fluid storage tanks on a liquefied gas carrier and a bladder positioned within the outer compartment, the controller configured to obtain a first temperature of a liquefied gas contained within the outer compartment and a second temperature of CO_2 contained within the bladder during unloading operations, onloading operations, and transport of the liquefied gas and CO_2;

a second input/output in signal communication with one or more pressure-control apparatuses positioned within the outer compartment of each of one or more dual-fluid storage tanks and the bladder, the controller configured to obtain a first pressure of the liquefied gas contained within the outer compartment and a second pressure of CO_2 contained within the bladder during the unloading operations, the onloading operations, and the transport of the liquefied gas and CO_2;

a third input/output in signal communication with a first flow meter positioned at a first inlet of the outer compartment and a second flow meter positioned at a second inlet of the bladder, the controller configured to measure a first flow rate of the liquefied gas and a second flow rate of the CO_2;

a fourth input/output in signal communication with a first control valve, the first control valve designed to adjust flow of the liquefied gas via one or more unloading/loading pumps positioned on the liquefied gas carrier thereby modifying the first flow rate of the liquefied gas, and a second flow control valve, the second control valve designed to adjust flow of the CO_2 via the one or more unloading/loading pumps thereby modifying the second flow rate, the controller configured to:

Date Reçue/Date Received 2023-08-18

after initiation of the unloading operations or the loading operations:

determine whether the first flow rate or the second flow rate is to be modified based on an outer compartment temperature, an outer compartment pressure, a bladder pressure, or a bladder temperature, and

in response to a determination that the first flow rate is to be modified:

adjust a position of the first flow control valve that adjusts flow of the liquefied gas, thereby modifying the first flow rate; and

in response to a determination that the second flow rate is to be modified:

adjust a position of the second flow control valve that adjusts flow of the CO_2, thereby modifying the second flow rate.

22. The controller of claim 21, wherein modification of the first flow rate or the second flow rate is based on a first amount of the liquefied gas within the outer compartment and a second amount of the CO_2 within the bladder.

23. The controller of claim 21, wherein modification of the first flow rate or the second flow rate is based on a third amount of the liquefied gas within one or more liquefied gas storage tanks positioned at a location and a second amount of the CO_2 within one or more CO_2 storage tanks.

Date Reçue/Date Received 2023-08-18

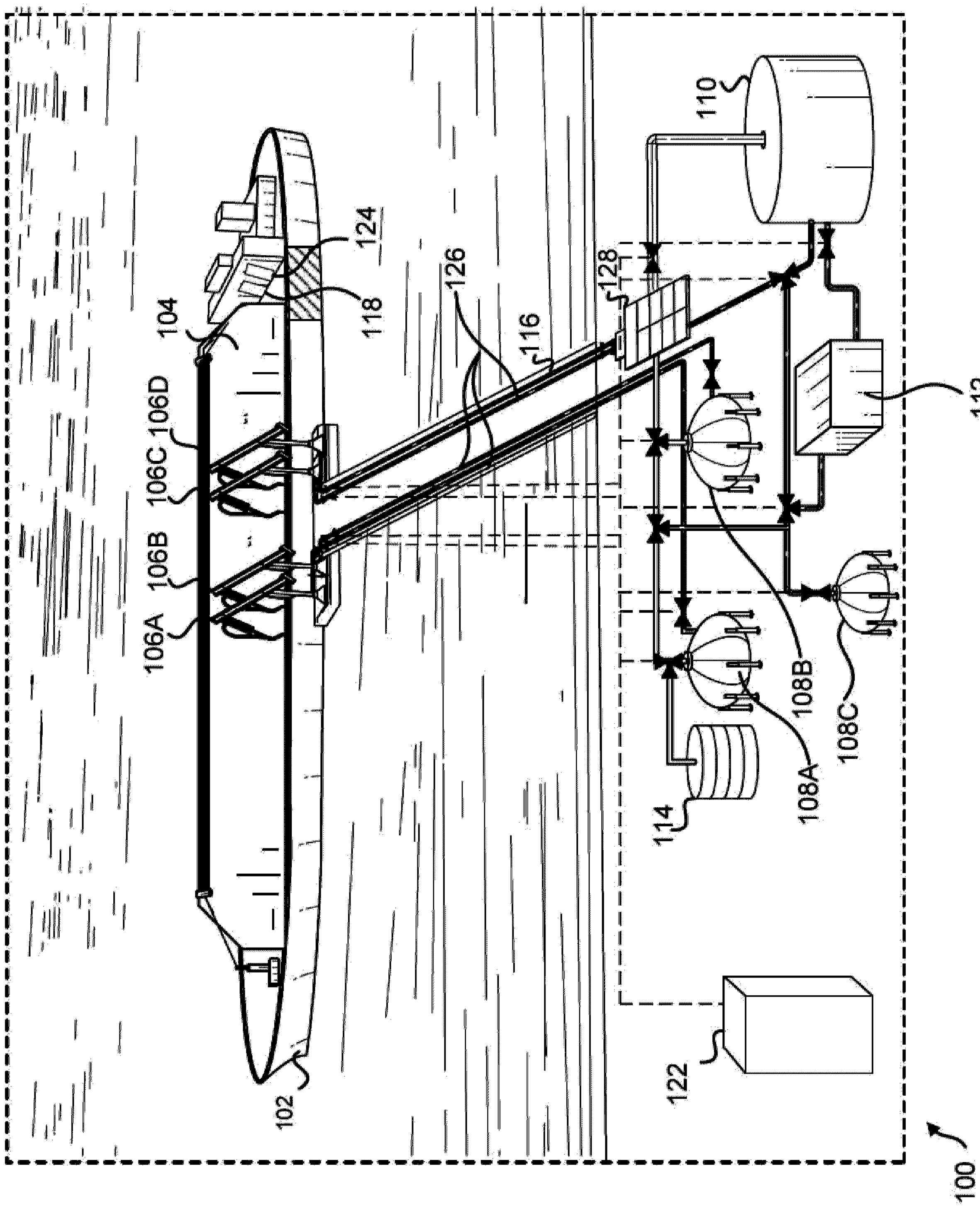

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FIG. 1

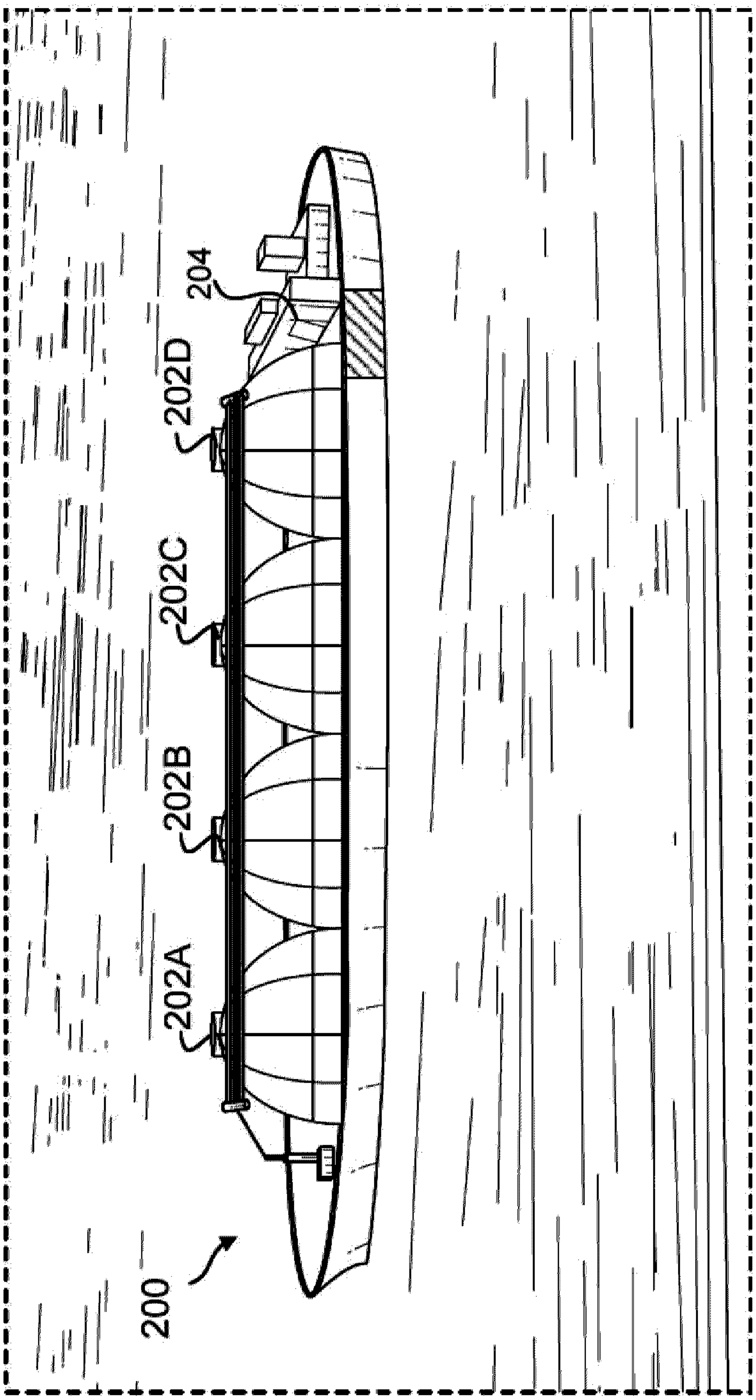

FIG. 2

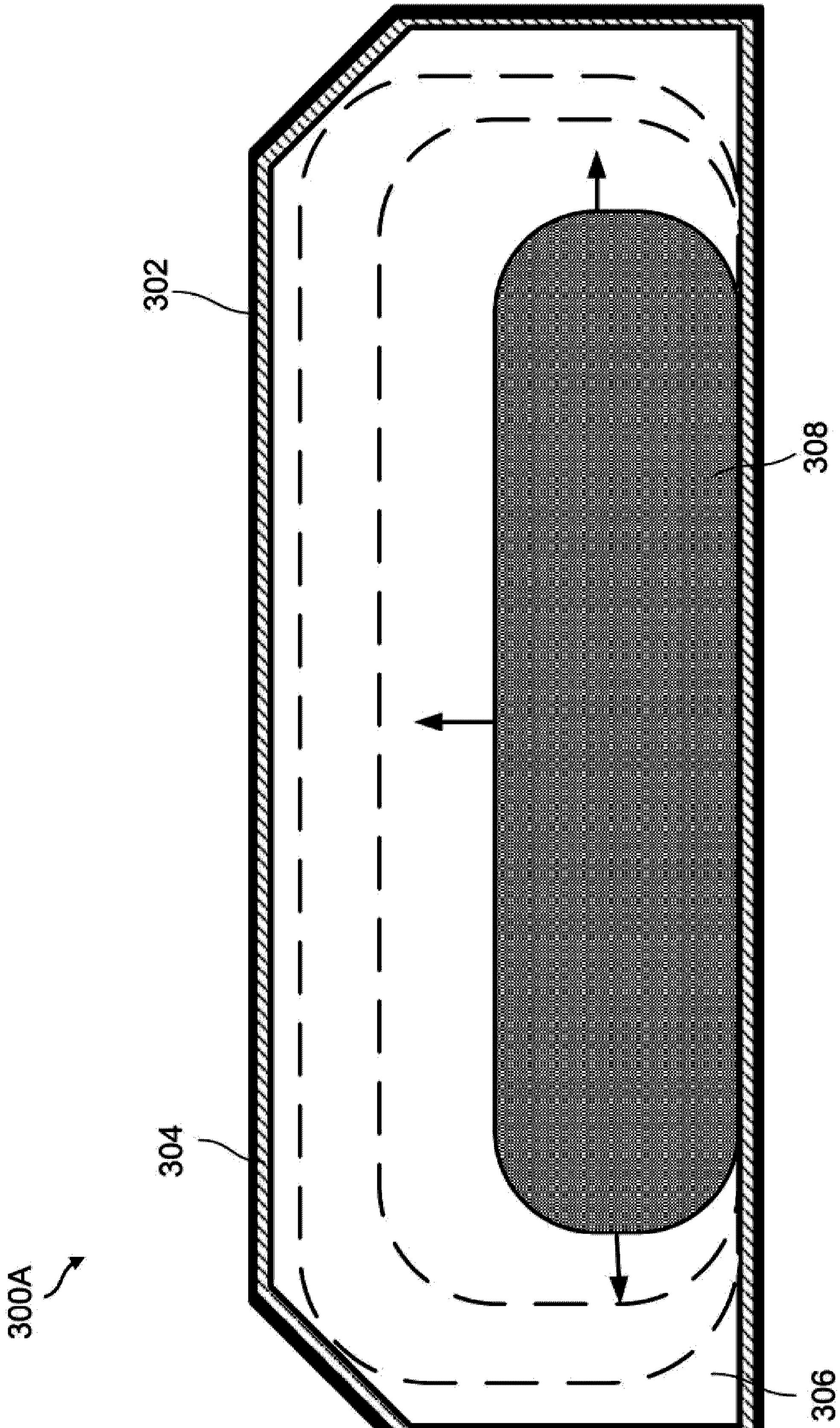

FIG. 3A

Date Reçue/Date Received 2023-08-18

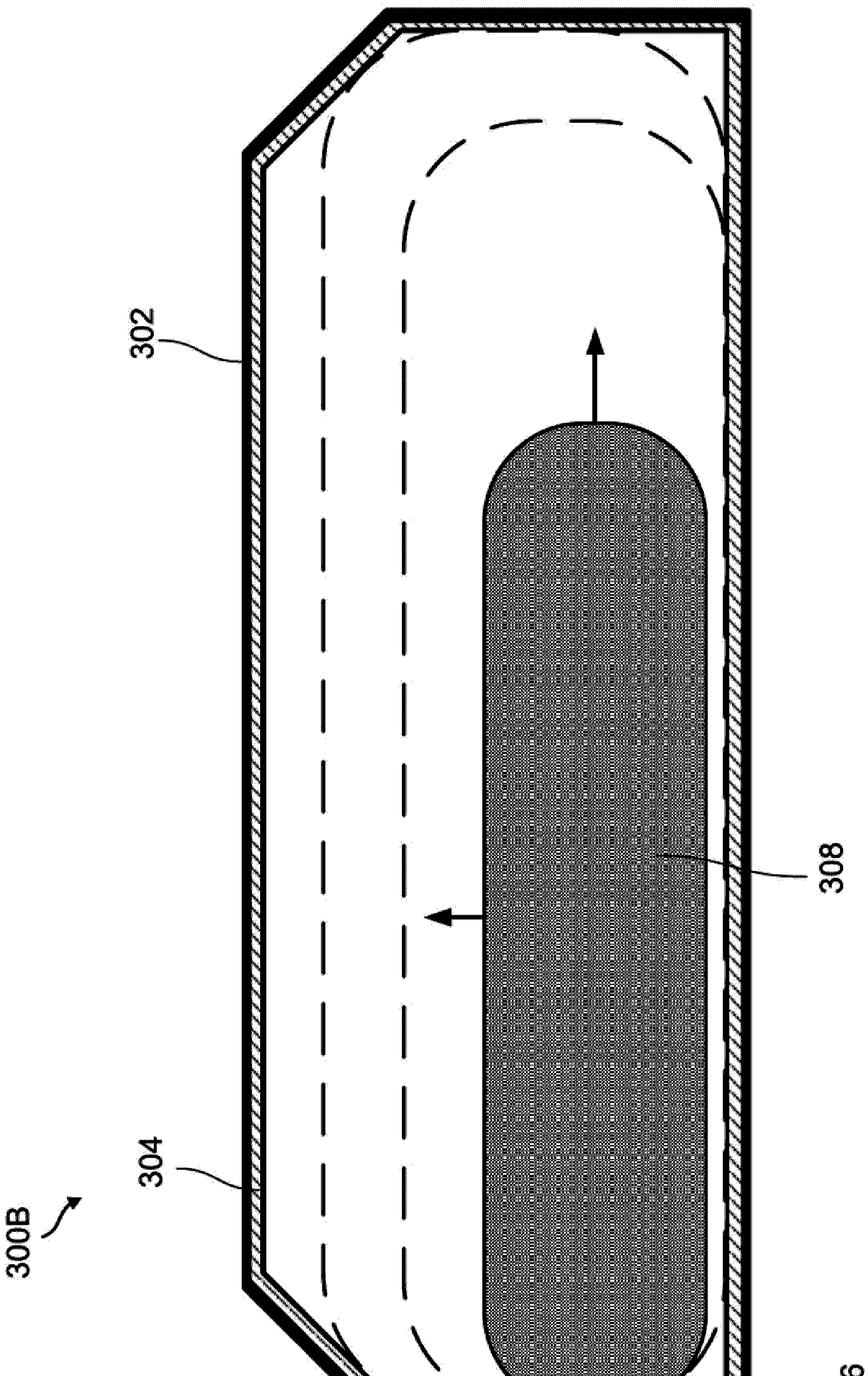

FIG. 3B

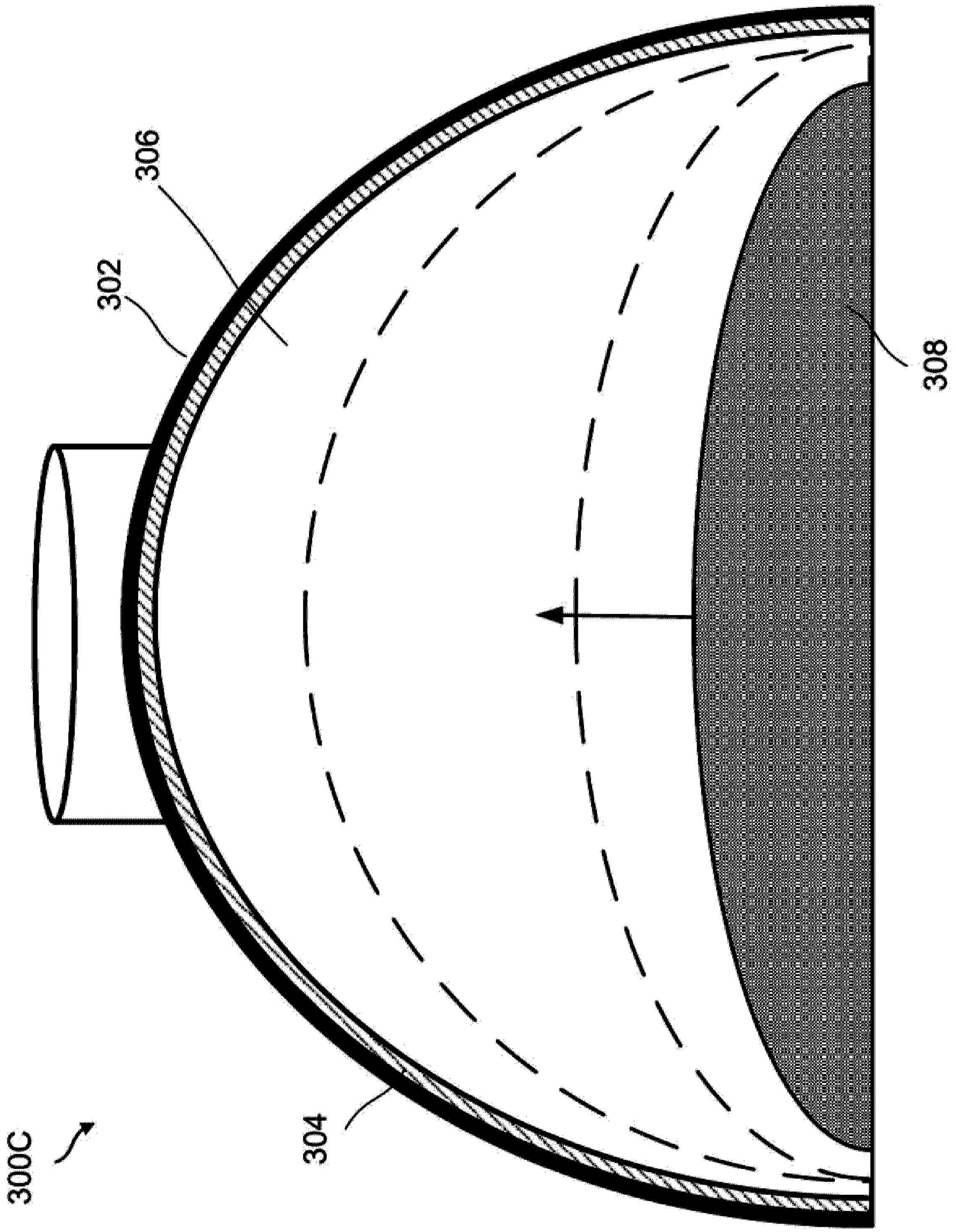

FIG. 3C

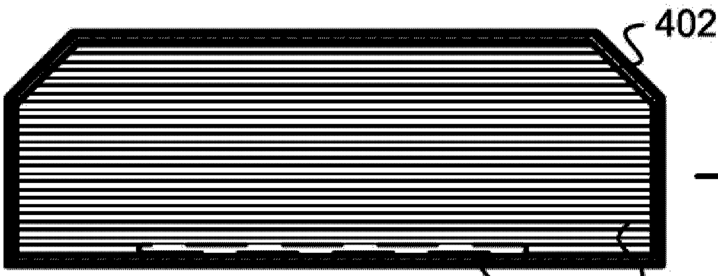

FIG. 4A

FIG. 4B

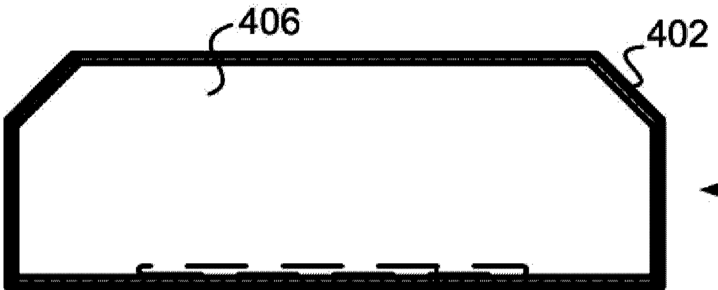

FIG. 4C

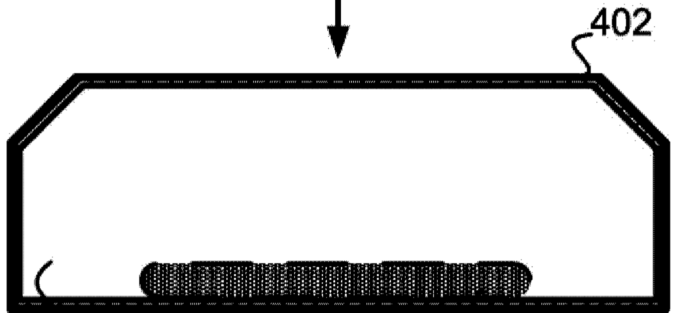

FIG. 4D

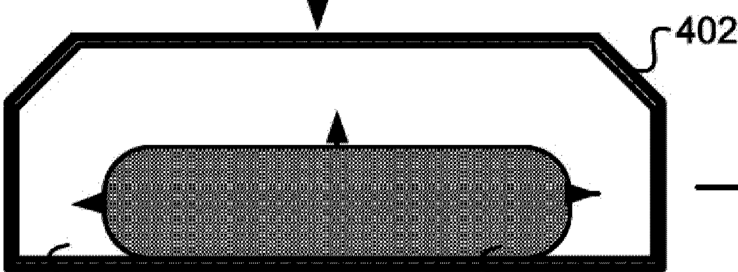

FIG. 4E

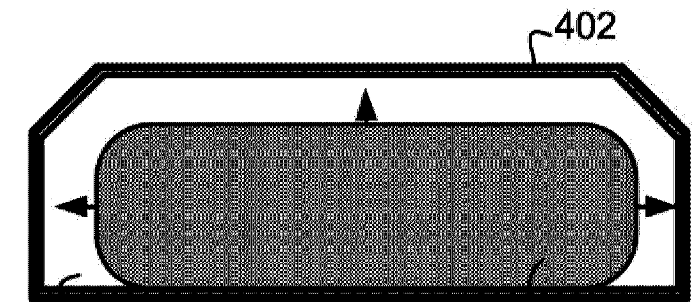

FIG. 4F

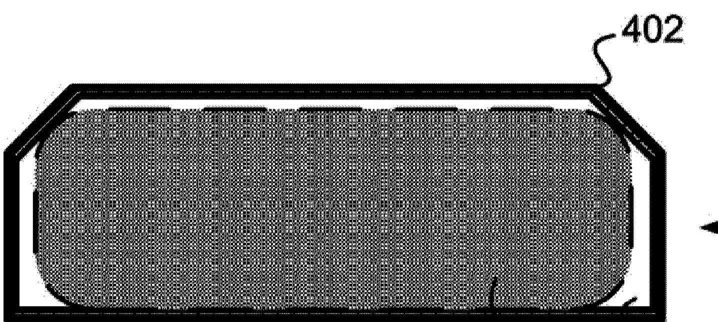

FIG. 4G

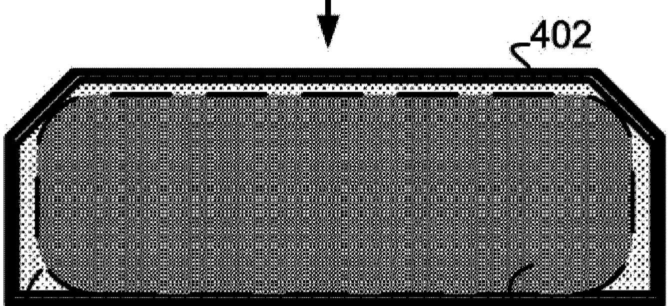

FIG. 4H

Date Reçue/Date Received 2023-08-18

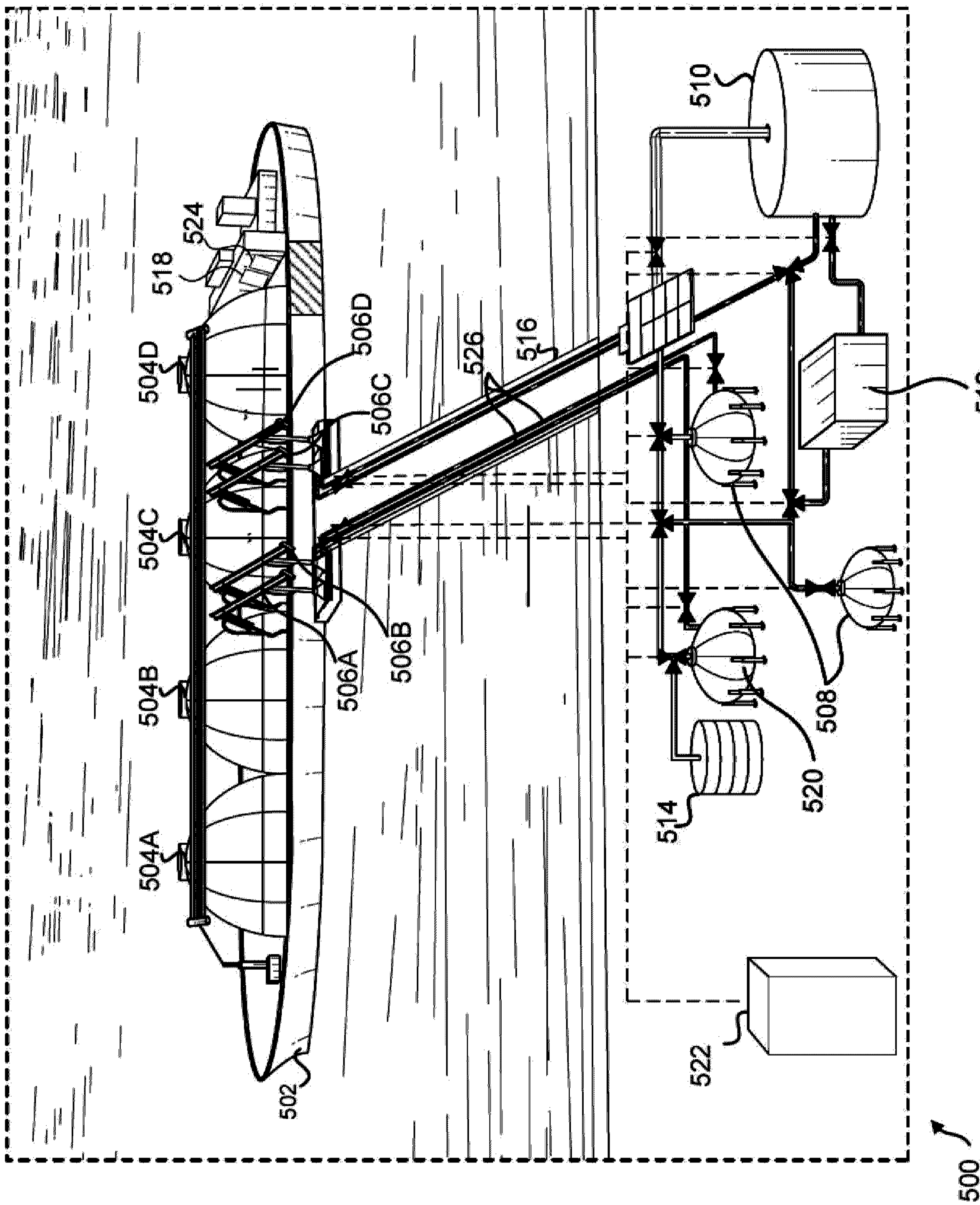

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FIG. 5

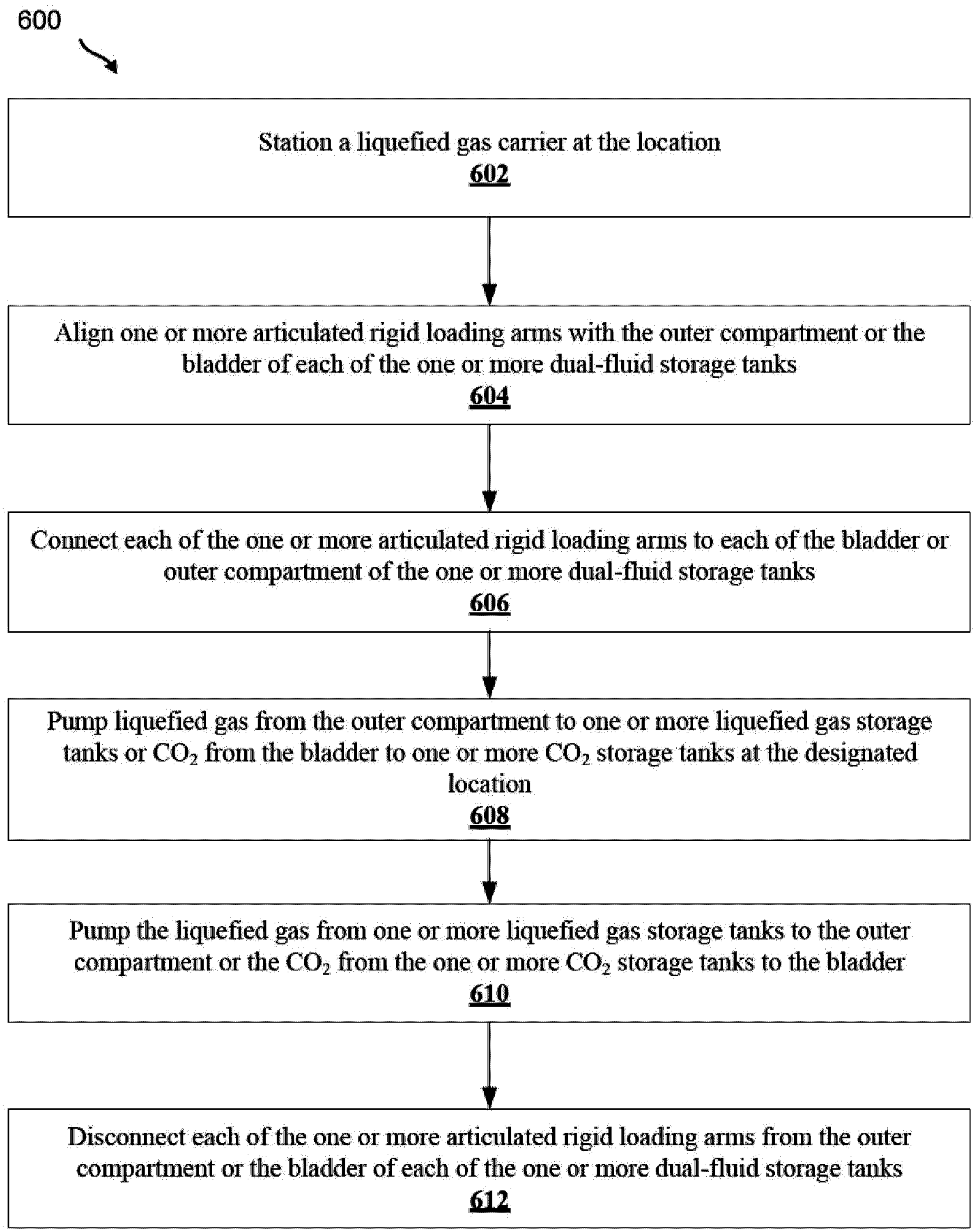

600
Station a liquefied gas carrier at the location
602
Align one or more articulated rigid loading arms with the outer compartment or the bladder of each of the one or more dual-fluid storage tanks
604
Connect each of the one or more articulated rigid loading arms to each of the bladder or outer compartment of the one or more dual-fluid storage tanks
606
Pump liquefied gas from the outer compartment to one or more liquefied gas storage tanks or CO_2 from the bladder to one or more CO_2 storage tanks at the designated location
608
Pump the liquefied gas from one or more liquefied gas storage tanks to the outer compartment or the CO_2 from the one or more CO_2 storage tanks to the bladder
610
Disconnect each of the one or more articulated rigid loading arms from the outer compartment or the bladder of each of the one or more dual-fluid storage tanks
612

FIG. 6

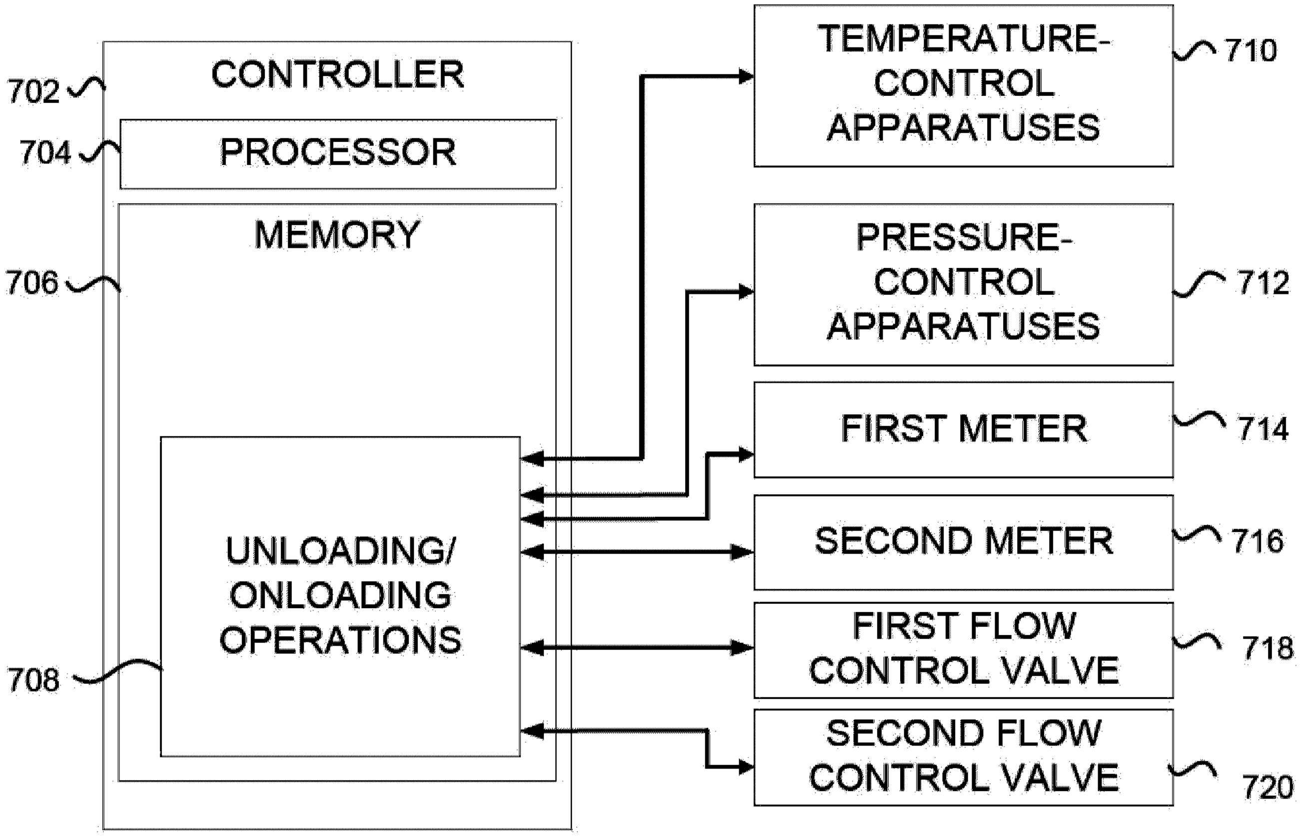


FIG. 7A

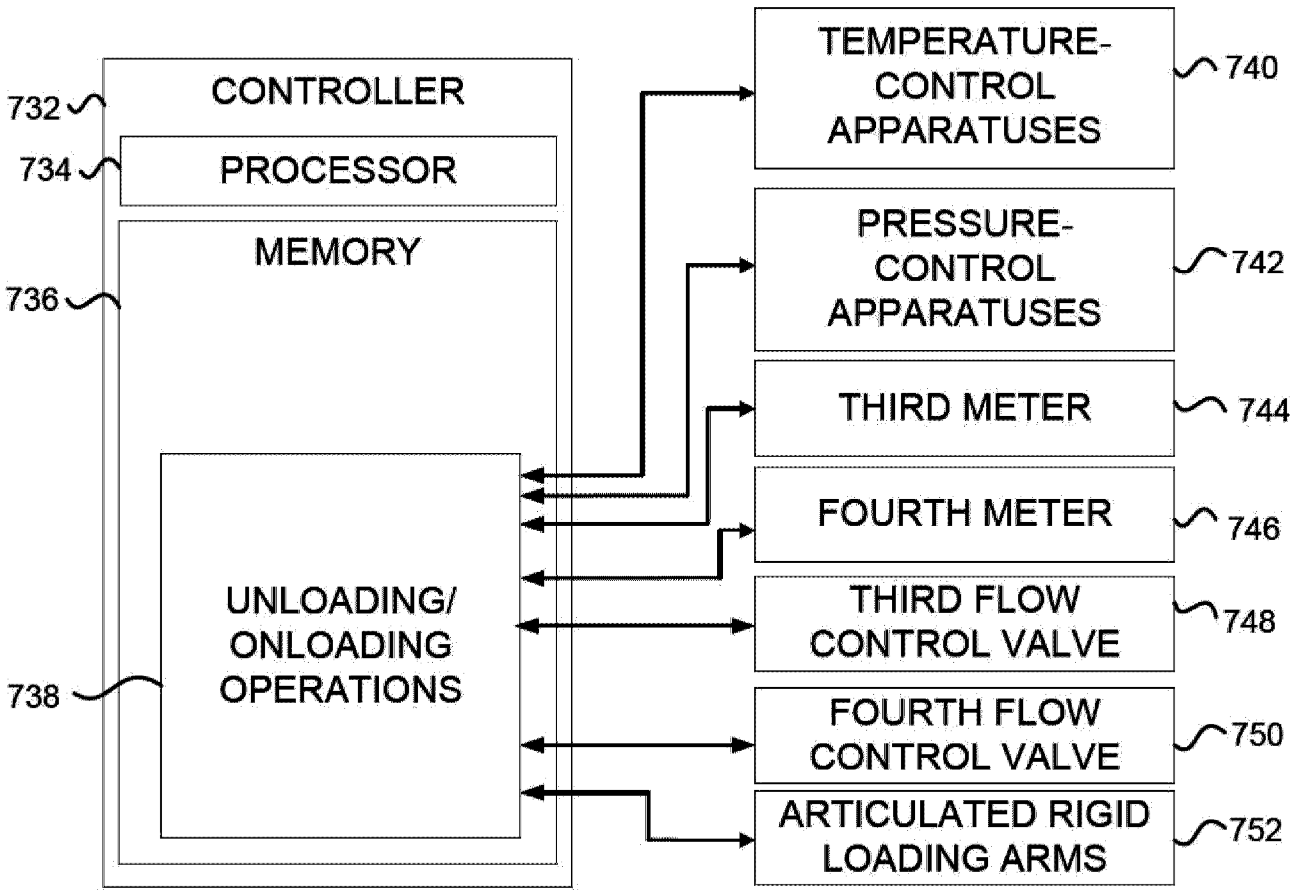


FIG. 7B

Date Reçue/Date Received 2023-08-18

FIG. 7C

Date Reçue/Date Received 2023-08-18

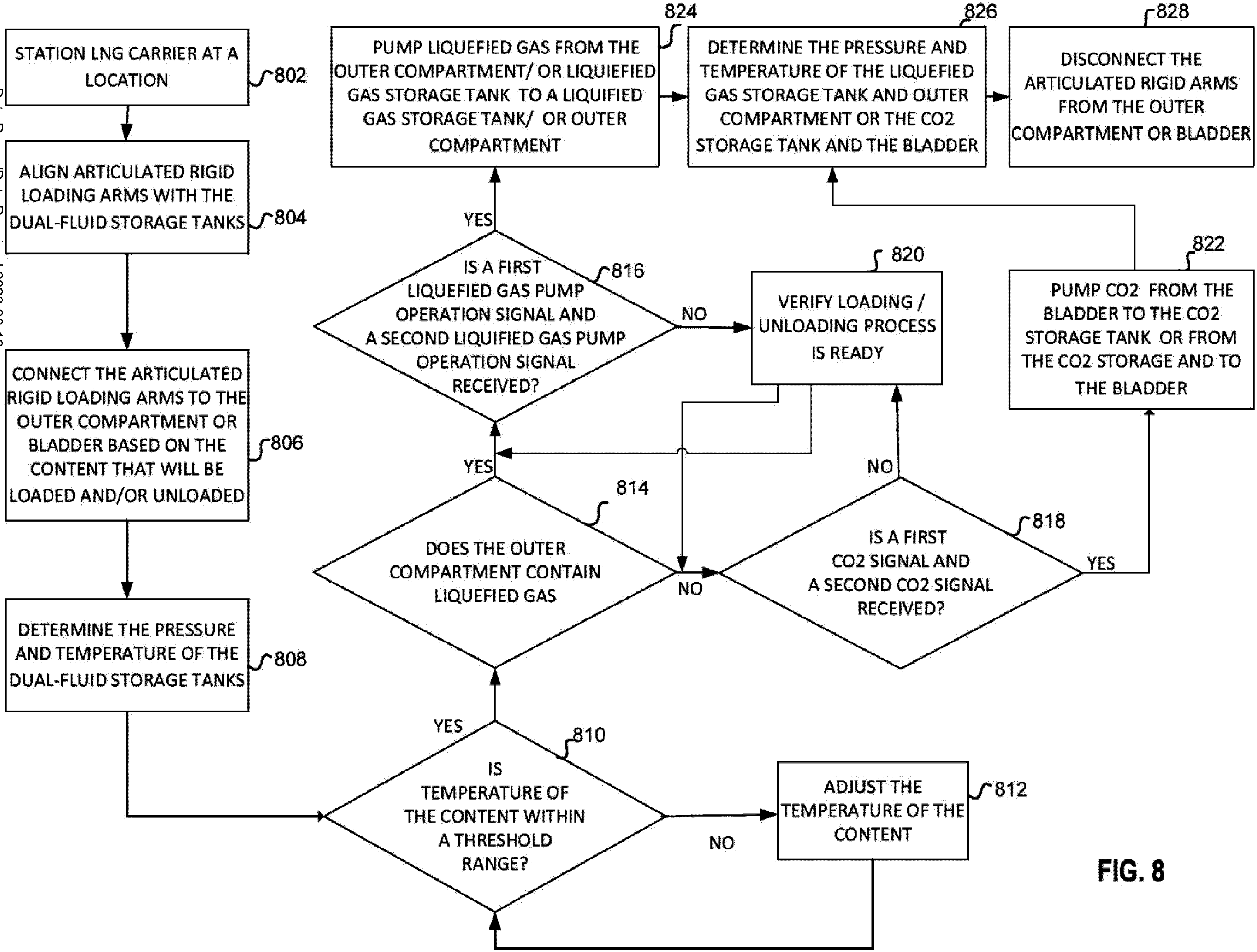
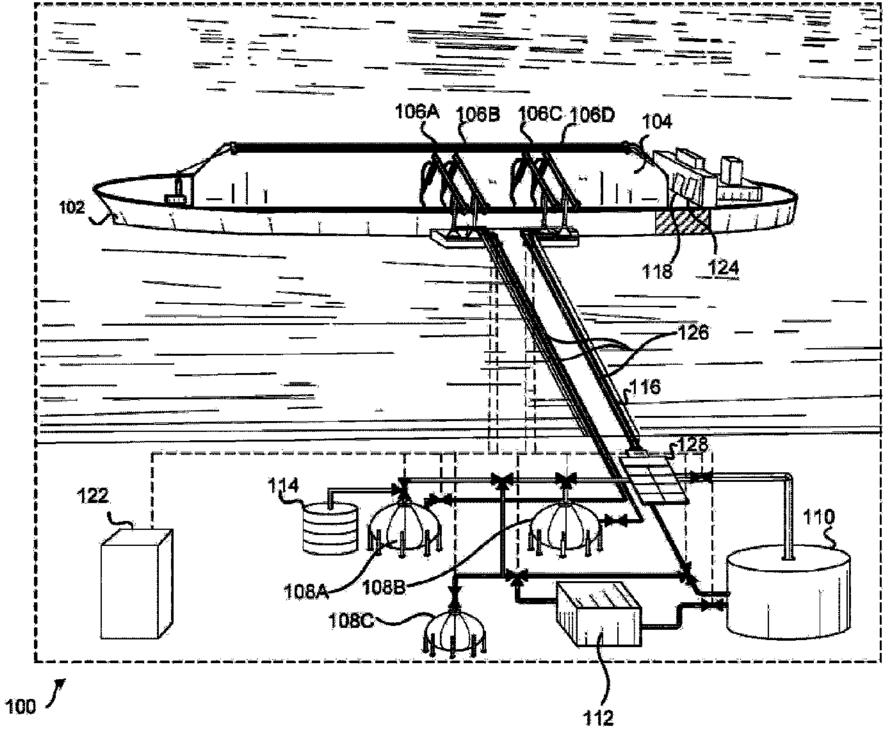


FIG. 8

Date Reçue/Date Received 2023-08-18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