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(54) **VARIABLE DENSITY AIRSHIP LIFT CHAMBER SYSTEM**

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B64B 1/62 (2006.01)
B64B 1/22 (2006.01)

(52) **U.S. Cl.**
CPC . ***B64B 1/62*** (2013.01); ***B64B 1/22*** (2013.01)

(58) **Field of Classification Search**
CPC B64B 1/62; B64B 1/22
See application file for complete search history.

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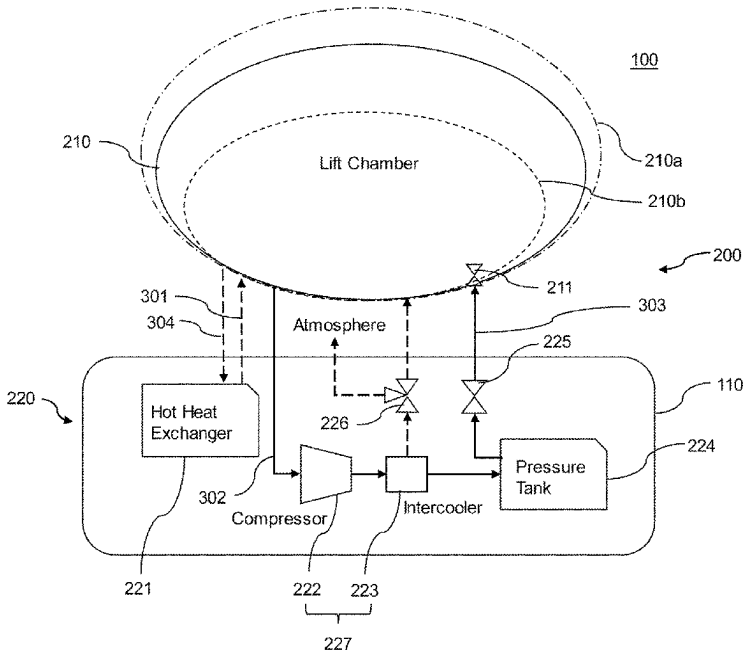
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Primary Examiner — Tye William Abell

(57) **ABSTRACT**

A variable density airship lift chamber system for airships provides more efficient lift control. The airship lift chamber system includes at least one lift chamber filled with lift gas and configured to provide lifting force, a heat exchanger configured to heat the lift gas in the at least one lift chamber, a compressor unit configured to withdraw the lift gas from the lift chamber and to compress the withdrawn lift gas, a pressure tank configured to store the withdrawn compressed lift gas from the compressor unit, a refrigeration orifice formed in the lift chamber, and a valve that connects the pressure tank to lift chamber through the refrigeration orifice. The airship lift chamber system controls density of the lift gas in the lift chamber by heating the gas while removing the gas from the lift chamber and by supplying gas into the lift chamber.

18 Claims, 4 Drawing Sheets



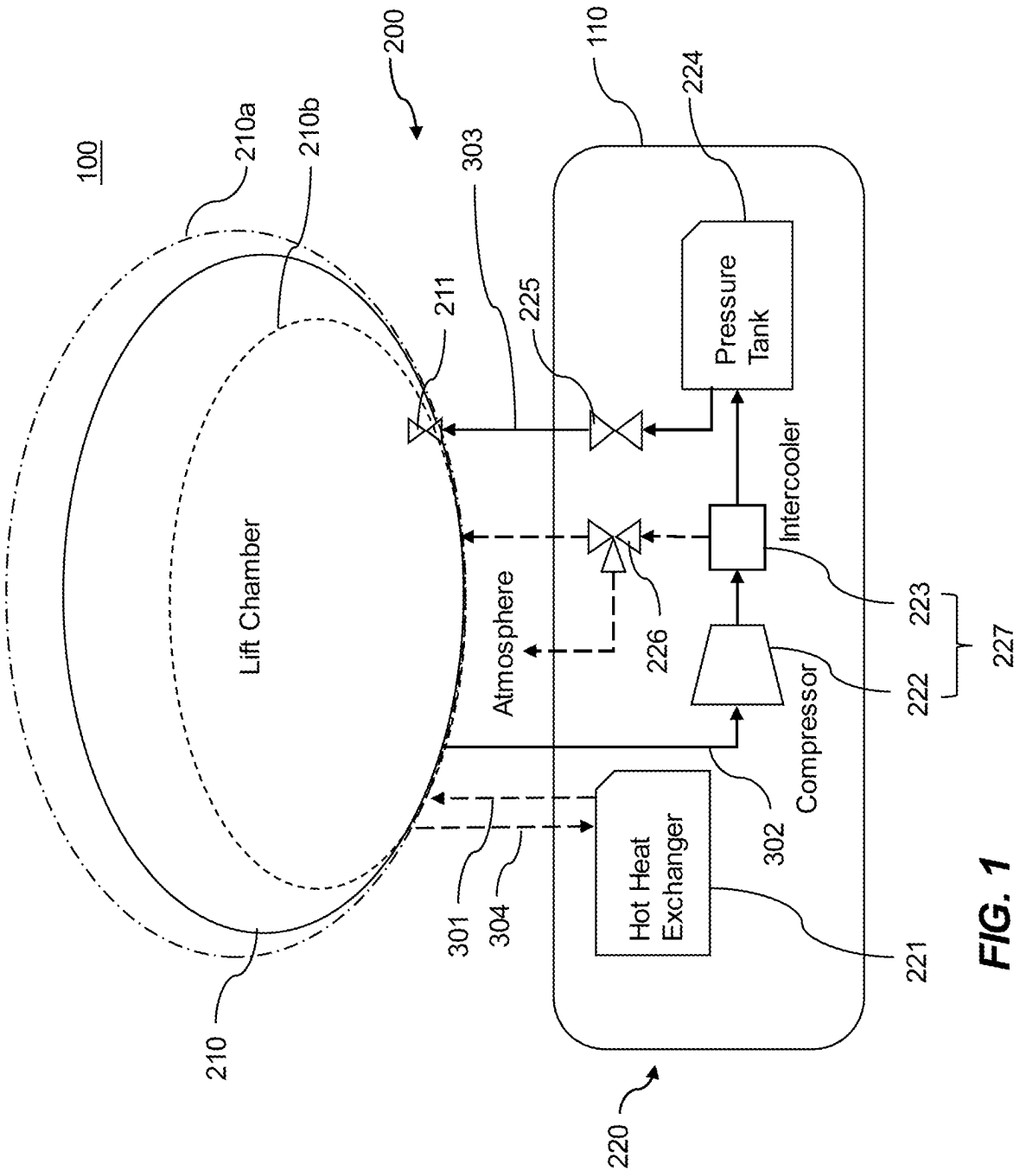

100
210a
210b
200
303
110
224
211
225
Pressure Tank
Lift Chamber
Intercooler
Atmosphere
226
223
222
227
Compressor
302
Hot Heat Exchanger
221
301
304
210
220

FIG. 1

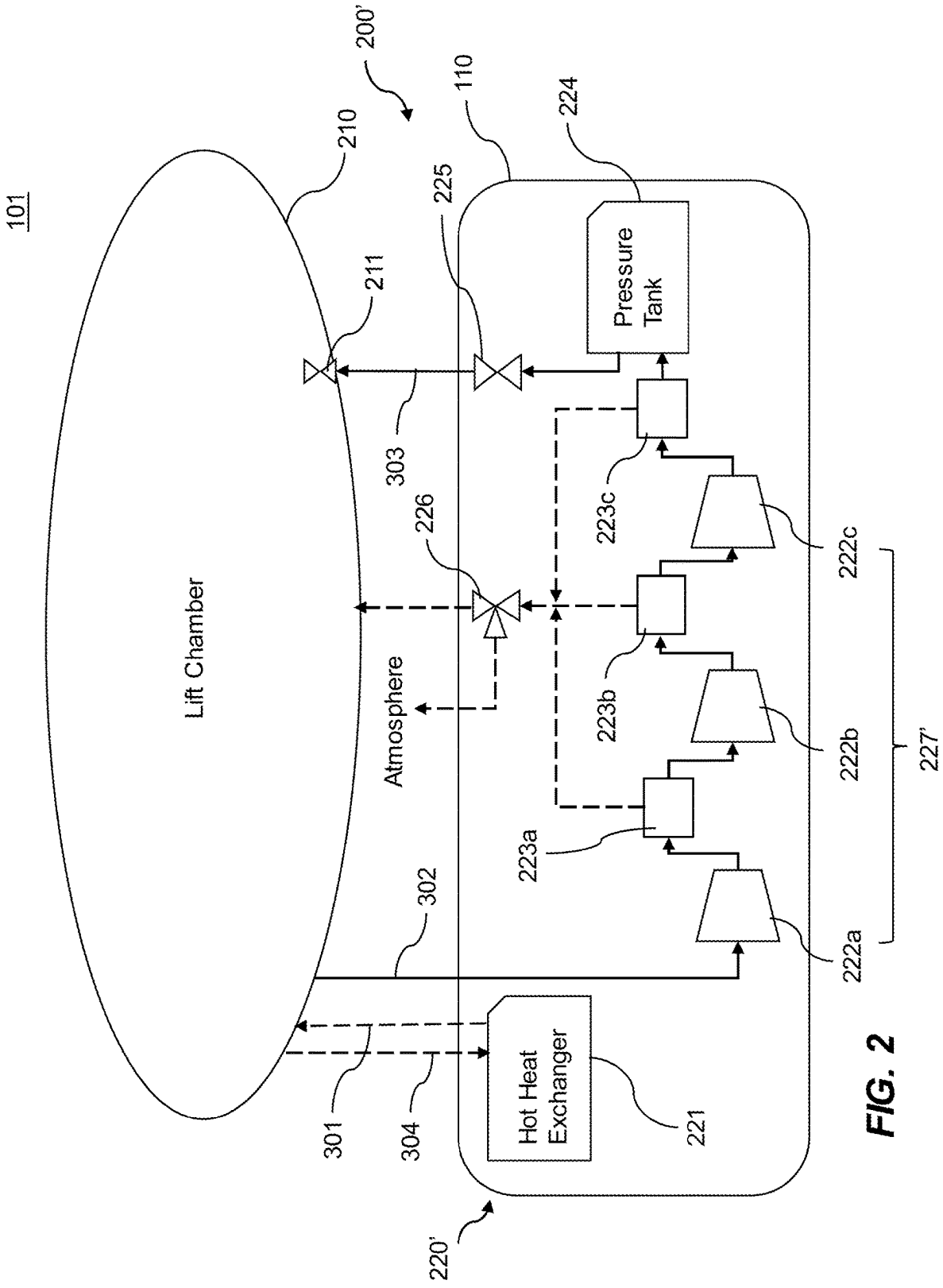

101
200'
110
210
224
225
211
Pressure Tank
303
223c
222c
226
Lift Chamber
Atmosphere
223b
222b
227'
223a
302
222a
Hot Heat Exchanger
221
301
304
220'

FIG. 2

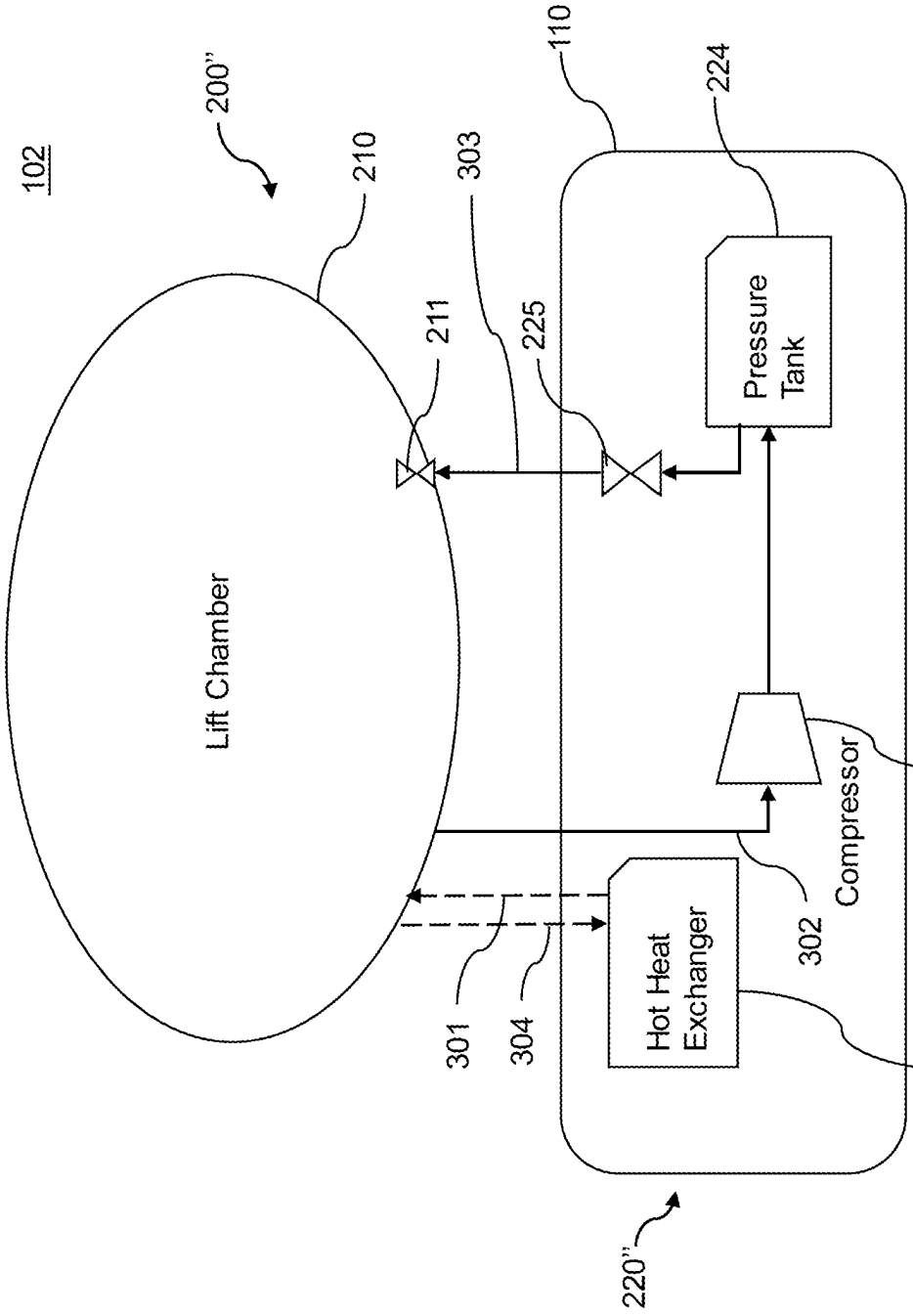

102
200"
210
303
110
224
211
225
Pressure Tank
Lift Chamber
222
227"
Compressor
302
Hot Heat Exchanger
221
301
304
220"

FIG. 3

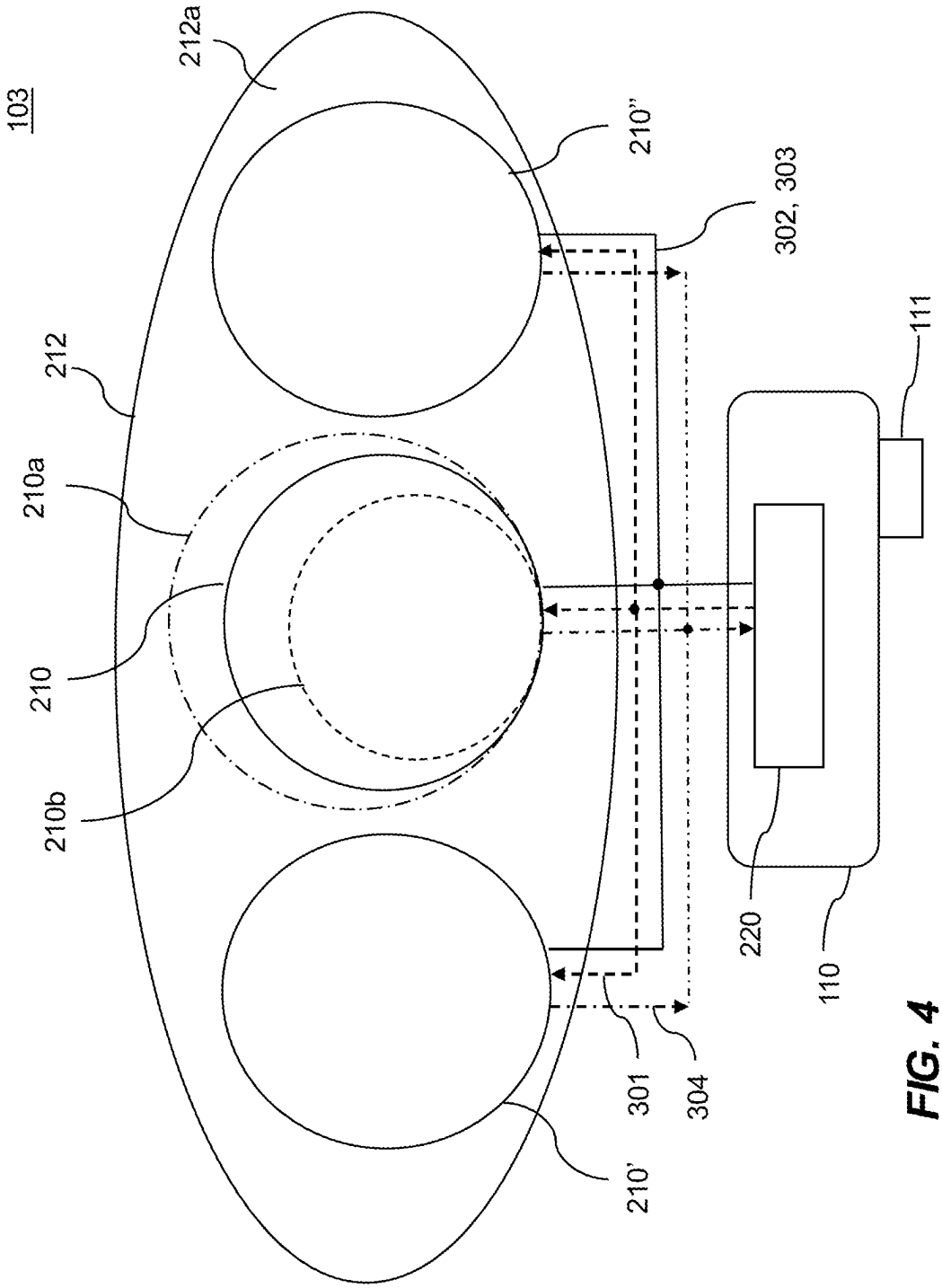


FIG. 4

VARIABLE DENSITY AIRSHIP LIFT CHAMBER SYSTEM

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims priority to U.S. Provisional Patent Application No. 63/312,479, filed Feb. 22, 2022, the entire contents of which are incorporated herein by reference.

BACKGROUND

Airship is lighter-than-air aircraft that can navigate through air with propulsion and steering systems. The lift force of the airship is provided by lifting gas contained in gasbags. The lifting gas in the gasbags is less dense than the surrounding air. The lifting force is produced by a difference in density between the lifting gas and the surrounding air. The airship may have an envelope that may include one or more gasbags to provide the lifting force, and may have a gondola suspended below the envelope. The gondola may include cabins for passengers and freight and may include control systems to control the navigation of the airship system. The gondola may be fitted with engines to provide propulsion of the airship system. As atmospheric pressure and air density change based on altitude, there is a need to efficiently manage the pressure and density of the lifting gas for smooth navigation of the airship through altitudes.

SUMMARY

The disclosed invention is directed to a variable density airship lift chamber system that can more efficiently manage the lifting force of the airship system, while controlling pressure inside the lift chamber to minimize stresses on the lift chamber caused by pressure difference.

These advantages and others are achieved, for example, by an airship lift chamber system for an airship. The airship lift chamber system includes at least one lift chamber filled with lift gas and configured to provide lifting force, a heat exchanger configured to heat the lift gas in the at least one lift chamber, a compressor unit configured to withdraw the lift gas from the lift chamber and to compress the withdrawn lift gas, a pressure tank configured to store the compressed withdrawn lift gas from the compressor unit, a refrigeration orifice formed in the lift chamber, and a valve that connects the pressure tank to lift chamber through the refrigeration orifice.

The compressor unit may include at least one compressor connected to the at least one lift chamber to withdraw the lift gas from the lift chamber and configured to compress the withdrawn lift gas. Alternatively, the compressor unit may include at least one compressor connected to the at least one lift chamber to withdraw the lift gas from the lift chamber and configured to compress the withdrawn lift gas, and at least one intercooler connected to the at least one compressor and configured to cool the compressed withdrawn lift gas from the compressor. The airship lift chamber system may further include a waste heat flow valve configured to transfer heat from the at least one intercooler to the lift chamber or atmosphere. The waste heat flow valve may be configured to transfer heat from the at least one intercooler to the atmosphere while the at least one compressor operates to provide more lift gas to the lift chamber from the pressure tank. The waste heat flow valve may be configured to transfer heat from the at least one intercooler to the lift chamber while the at least one compressor operates to store the lift gas in the pressure tank. The valve may be configured to be closed while the heat exchanger heats the lift gas. The lift gas may be lighter-than-air gas. The lift chamber may be a variable volume chamber that is configured to be expandable and shrinkable.

These advantages and others are also achieved, for example, by an airship system that includes at least one lift chamber filled with lift gas and configured to provide lifting force, a gondola connected to the at least one lift chamber and comprising at least one lift chamber control unit, a refrigeration orifice formed in the lift chamber, and a valve that connects the pressure tank to lift chamber through the refrigeration orifice. The at least one lift chamber control unit includes a heat exchanger configured to heat the lift gas in the at least one lift chamber, a compressor unit configured to withdraw the lift gas from the lift chamber and to compress the withdrawn lift gas, and a pressure tank configured to store the compressed withdrawn lift gas from the compressor unit.

BRIEF DESCRIPTION OF THE DRAWINGS

The preferred embodiments described herein and illustrated by the drawings hereinafter be to illustrate and not to limit the invention, where like designations denote like elements.

FIG. **1** is a diagram schematically illustrating an embodiment of the variable density airship lift chamber system of the disclosed invention.

FIG. **2** is a diagram schematically illustrating another embodiment of the variable density airship lift chamber system of the disclosed invention, which includes multiple stage compression.

FIG. **3** is a diagram schematically illustrating another embodiment of the variable density airship lift chamber system of the disclosed invention, which is constructed without intercoolers.

FIG. **4** is a diagram schematically illustrating an embodiment of an airship system having multiple lift chambers placed in an envelope.

DETAILED DESCRIPTION

The following detailed description is merely exemplary in nature and is not intended to limit the described embodiments or the application and uses of the described embodiments. All of the implementations described below are exemplary implementations provided to enable persons skilled in the art to make or use the embodiments of the disclosure and are not intended to limit the scope of the disclosure, which is defined by the claims. It is also to be understood that the drawings included herewith only provide diagrammatic representations of the presently preferred structures of the present invention and that structures falling within the scope of the present invention may include structures different than those shown in the drawings.

The variable density airship lift chamber system of the disclosed invention includes one or more devices to heat and cool lift gas in the lift chamber, and one or more devices to add lift gas to the lift chamber and to subtract lift gas from the lift chamber. The lift chamber is a variable volume chamber that can expand and shrink based on pressure, temperature and amount (number of particles) of lift gas in the chamber. It may be ideal to control the amount of lift gas to maintain a substantially constant or optimum pressure within the lift chamber that may be approximately equal to

or slightly higher than atmospheric pressure acting on the exterior of the lift chamber for minimum stresses on the lift chamber.

With reference to FIG. **1**, shown is a diagram of an airship system **100** that includes an embodiment of the variable density airship lift chamber system **200** of the disclosed invention. The airship system **100** includes at least one lift chamber **210** that is filled with lift gas to provide lifting force and gondola **110** coupled to the lift chamber **210**. The airship system **100** may further include one or more engines **111** (see FIG. **4**) that are coupled to the gondola **110** and are configured to provide propulsion to the gondola **110** and lift chamber **210** to move the airship system **100** in a desired direction. The engines **111** may include typical engines that can be used for airships. The lift gas may be lighter-than-air gas such as helium. The lift chamber **210** is a variable volume chamber that is configured to be expandable and shrinkable so that the volume of the lift chamber **210** changes based on pressure, temperature and amount of lift gas in the lift chamber **210**. FIG. **1** exemplarily shows variable volumes **210***a*, **210***b* of the lift chamber **210**. For example, when the lift gas in the lift chamber **210** is heated, the lift chamber **210** may expand to the larger volume **210***a*, and when the lift gas in the lift chamber **210** is cooled, the lift chamber **210** may shrink to the smaller volume **210***b*.

The airship lift chamber system **200** of the disclosed invention includes lift chamber **210**, refrigeration orifice **211** located inside or on a surface of the lift chamber **210**, and lift chamber control unit or system **220** that is configured to control density and pressure of the lift gas in the lift chamber **210**. The lift chamber control unit **220** may be placed in the gondola **110**. The lift chamber control unit **220** includes heat exchanger **221**, compressor unit **227**, pressure tank **224**, and valve **225**. The refrigeration orifice **211** is connected to the pressure tank **224** through line **303** and the valve **225**. In an embodiment, the compressor unit **227** includes at least one compressor **222**. In another embodiment, the compressor unit **227** includes at least one compressor **222** and at least one intercooler **223** connected to the compressor **222**. When the compressor unit **227** includes at least one intercooler **223**, the lift chamber control unit **220** further includes waste heat flow valve **226** connected to the intercooler **223** to transfer heat from the intercooler **223** to atmosphere or the lift chamber **210**, as shown in FIG. **1**. The functionalities of these components are described below.

When more lifting force is needed, the lift gas in the lift chamber **210** flows through line **304** to heat exchanger **221** that adds heat and increases the lift gas temperature before returning to the lift chamber **210** through line **301**. While the lift gas is heated, the lift chamber **210** may expand, increasing its volume, ideally to the point that equilibrium is reached between atmospheric pressure and pressure of the lift gas inside the lift chamber **210**. The increased volume of the lift chamber **210** increases lifting force of the lift chamber **210**. However, in order to control expansion of the volume of the lift chamber **210** and/or to prevent over-expansion of the lift chamber **210**, the lift gas may be also removed from the lift chamber **210** by operating compressor **222** connected to the lift chamber **210** through line **302**. Removing lift gas from the lift chamber **210** effectively reduces the pressure inside the lift chamber **210**. For example, as long as the pressure in the lift chamber **210** is higher than or equal to ambient air pressure, the volume may not be reduced even though gas is removed from the lift chamber **210**. At this condition, lifting force generated by the volume is maintained while pressure in the chamber may be reduced or controlled to prevent over-expansion of the lift chamber **210**. In this way, the pressure in the lift chamber **210** can be controlled, while increasing or decreasing lifting force of the lift chamber **210** by the volume of the lift chamber **210**. The lift gas removed from the lift chamber **210** is compressed by the compressor **222** and is supplied to the pressure tank **224** that stores the compressed lift gas until the lift gas is needed to increase density and lower temperature. At this stage, the valve **225** is closed. The heat exchanger **221** can be heated by waste heat from a power plant or heat from a biochar making system or both.

When the lifting force needs to be reduced, the heat exchanger **221** may stop heating the lift gas in the lift chamber **210**. Consequently, the volume of the lift chamber **210** decreases as the lift chamber **210** cools down, lowering lifting force. At this stage, the valve **225**, which connects the pressure tank **224** to the lift chamber **210** through line **303**, is opened and the compressed lift gas stored in the pressure tank **224** flows into the lift chamber **210** through the valve **225** and the refrigeration orifice **211**. The compressed lift gas flowing into the lift chamber **210** may provide refrigerating effect in the lift chamber **210**, accelerating the cooling of the lift chamber **210**. Furthermore, it is possible to create more cooling by running compressor **222** and returning the compressed lift gas through the refrigeration orifice **211** to cool the lift gas in the lift chamber **210** more.

As shown in FIG. **1**, the compressed lift gas is supplied to the pressure tank **224** through intercooler **223**. Compressing lift gas to remove it from the lift chamber **210** will heat the gas, and it is desirable to cool the gas after compression to store more gas in the pressure tank **224**. The use of intercooler **223** between compression stage and after compression cuts compressor work, increases storage of the pressure tank **224**, and provides more heat when needed to heat lift gas in lift chamber **210**. For example, if the compressor **222** is being run to provide more gas for the refrigeration orifice **211** to increase the density of the lift gas in the lift chamber **210**, then it is desirable to dissipate heat from the intercooler **223** into the atmosphere. However, if the compressor **222** is run to lower the density of lift gas in the lift chamber **210** while the lift gas is heated, then it is desirable that the waste heat be supplied to the lift gas inside the lift chamber **210**. The waste heat flow valve **226** connected between the intercooler **223** and the lift chamber **210** works as a switch to direct the heat from the intercooler **223** into atmosphere or into the lift chamber **210**.

With reference to FIG. **2**, shown is a diagram of an airship system **101** that includes another embodiment of the variable density airship lift chamber system **200'** of the disclosed invention that includes lift chamber **210**, refrigeration orifice **211**, and lift chamber control unit **220'**. The lift chamber **210** is a variable volume chamber that can expand and shrink as shown in FIG. **1**. The difference is that compressor unit **227'** of the lift chamber control unit **220'** includes multiple stage compression which would be needed for high pressure storage. For the multiple stage compression, intercooling between stages is desirable as well as at final pressure. FIG. **2** exemplarily shows the compressor unit **227'** that includes three compressors **222***a*, **222***b*, **222***c* and three intercoolers **223***a*, **223***b*, **223***c* coupled to the compressors. However, any number of the compressors and intercoolers may be employed depending on needs for pressure storage.

With reference to FIG. **3**, shown is a diagram of an airship system **102** that includes another embodiment of the variable density airship lift chamber system **200"** of the disclosed invention that includes lift chamber **210**, refrigeration orifice **211**, and lift chamber control unit **220"**. The lift chamber **210** is a variable volume chamber that can expand and shrink as

shown in FIG. **1**. In this embodiment, the compressor unit **227"** includes compressor **222** without intercooler.

With reference to FIG. **4**, shown is a diagram of airship system **103** having multiple lift chambers **210**, **210'**, **210"**. The lift chamber **210** may be the variable volume chamber described above, while the other lift chambers **210'**, **210"** may be variable volume lift chambers or any other conventional type lift chambers. The variable volume lift chamber **210** is connected to the components in the lift chamber control unit **220** as described above referring to FIG. **1**, **2** or **3**. If the lift chambers **210'**, **210"** are variable volume chambers, lift chambers **210**, **210'**, **210"** may be all connected to lift chamber control unit **220** that includes a heat exchanger **221**, as shown in FIGS. **1-3**, which adds heat to the lift gas flowing from the lift chambers **210**, **210'**, **210"** through lines **304** and supplies the heated lift gas to the lift chamber **210**, **210'**, **210"** through lines **301**. The lift chamber control unit **220** includes the components that are described above referring to FIG. **1**, **2** or **3**. The lift chambers **210**, **210'**, **210"** may be connected to compressor **222** and pressure tank **224** through lines **302**, **303**, as shown in FIGS. **1-3**. FIG. **4** exemplarily shows three lift chambers, but the airship system **103** may have any number of the lift chambers based on applications.

The lift chambers **210**, **210'**, **210"** may be placed inside an envelope **212**. In an embodiment, the inner space **212***a* of the envelope **212** (outside the lift chambers **210**, **210'**, **210"**) may be open to atmosphere. In another embodiment, the envelope **212** may be configured to control density of the air in the inner space **212***a*. In this case, the envelope **212** may have a vent opening (not shown) controlled by one or more air pumps (not shown). The air pumps may be operated to draw air into the inner space **212***a* or to exhaust air from the inner space **212***a* through the vent opening. By controlling air density in the inner space **212***a* of the envelope **212**, the lifting force of the airship system **103** may be further controlled.

A combination of lighter-than-air gas with heating produces more lift and the ability to support more weight. With sufficient lift, a large airship could be used to lift trees selectively harvested from a remote forest, for processing in a facility suspended above the forest by the airship. The facility could cut the wood for lumber and use some of the rest for conversion to biochar to be reincorporated into the forest below or transported by the airship to desert or agricultural lands that need it. A few workers could either live on the airship and/or be ferried to it by, for example, a helicopter. Such a craft would be tethered by cables to the ground and be partially supported by power-generating kites or wind turbines.

The airship system of the disclosed invention provides a closed system of the lift gas by using the pressure tank **224** that stores the lift gas withdrawn from the lift chamber **210**. The lift gas stored in the pressure tank **224** is supplied to the lift chamber **210** when necessary. In this configuration, the airship system of the disclosed invention provides advantages that loss of the lift gas in the airship system is minimized, which may reduce the operating cost of the airship system. Preventing loss of the lift gas is important in practical applications, especially when the lift gas is precious commodity or supply of the lift gas is limited. For example, helium supplies are valuable and of finite supply. Once released, the helium gas escapes to earth's atmosphere and never returns to the airship. Conservation of helium is important and operating a large fleet of airships would need a lift gas storage/conservation method while adjusting lift force. Adjusting the buoyancy lift force of airships by compressing and storing airship lift gas for future use eliminates the need to expel lift gas into the atmosphere.

Since many modifications, variations, and changes in detail can be made to the described preferred embodiments of the invention, it is intended that all matters in the foregoing description and shown in the accompanying drawings be interpreted as illustrative and not in a limiting sense. Consequently, the scope of the invention should be determined by the appended claims and their legal equivalents.

What is claimed is:

1. An airship lift chamber system for an airship, comprising:

at least one lift chamber filled with lift gas and configured to provide lifting force;

a heat exchanger configured to:

receive the lift gas through a first gas line directly connected to the at least one lift chamber;

heat the lift gas in the at least one lift chamber; and

return the heated lift gas through a second gas line directly connected to the at least one lift chamber;

a compressor configured to withdraw the lift gas from the lift chamber and to compress the withdrawn lift gas;

a pressure tank configured to store the compressed lift gas from the compressor;

a refrigeration orifice formed in the lift chamber; and

a valve that connects the pressure tank to lift chamber through the refrigeration orifice.

2. The airship lift chamber system of claim **1**, wherein the compressor comprises multiple compressors connected to the at least one lift chamber to withdraw the lift gas from the lift chamber and configured to compress the withdrawn lift gas.

3. The airship lift chamber system of claim **1**, wherein the valve is configured to be closed while the heat exchanger heats the lift gas.

4. The airship lift chamber system of claim **1**, wherein the lift gas is lighter-than-air gas.

5. The airship lift chamber system of claim **1**, wherein the lift chamber is a variable volume chamber that is configured to be expandable and shrinkable.

6. The airship lift chamber system of claim **1**, further comprising:

an intercooler connected to the compressor and configured to cool the compressed lift gas from the compressor.

7. The airship lift chamber system of claim **6**, further comprising a waste heat flow valve configured to transfer heat from the intercooler to at least one of the lift chamber and atmosphere.

8. The airship lift chamber system of claim **7**, wherein the waste heat flow valve is further configured to transfer heat from the intercooler to the atmosphere while the compressor operates to provide more lift gas to the lift chamber from the pressure tank.

9. The airship lift chamber system of claim **7**, wherein the waste heat flow valve is further configured to transfer heat from the intercooler to the lift chamber while the compressor operates to store the lift gas in the pressure tank.

10. An airship system, comprising:

at least one lift chamber filled with lift gas and configured to provide lifting force;

a gondola connected to the at least one lift chamber and comprising at least one lift chamber control unit that comprises:

a heat exchanger configured to:

receive the lift gas through a first gas line directly connected to the at least one lift chamber;

heat the lift gas in the at least one lift chamber; and return the heated lift gas through a second gas line directly connected to the at least one lift chamber;

a compressor configured to withdraw the lift gas from the lift chamber and to compress the withdrawn lift gas; and

a pressure tank configured to store the compressed lift gas from the compressor;

a refrigeration orifice formed in the lift chamber; and

a valve that connects the pressure tank to lift chamber through the refrigeration orifice.

11. The airship system of claim **10**, wherein the compressor comprises multiple compressors connected to the at least one lift chamber to withdraw the lift gas from the lift chamber and configured to compress the withdrawn lift gas.

12. The airship system of claim **10**, wherein the valve is configured to be closed while the heat exchanger heats the lift gas.

13. The airship system of claim **10**, wherein the lift gas is lighter-than-air gas.

14. The airship system of claim **10**, wherein the lift chamber is a variable volume chamber that is configured to be expandable and shrinkable.

15. The airship system of claim **10**, further comprising:

an intercooler connected to the compressor and configured to cool the compressed lift gas from the compressor.

16. The airship system of claim **15**, further comprising a waste heat flow valve configured to transfer heat from the intercooler to at least one of the lift chamber and atmosphere.

17. The airship system of claim **13**, wherein the waste heat flow valve is further configured to transfer heat from the intercooler to the atmosphere while the compressor operates to provide more lift gas to the lift chamber from the pressure tank.

18. The airship system of claim **16**, wherein the waste heat flow valve is further configured to transfer heat from the intercooler to the lift chamber while the compressor operates to store the lift gas in the pressure tank.

* * * * *