

[54] AIRSHIP WITH INTERNAL TRANSFER
OF LIFTING GAS

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[51] Int. Cl.B64b 1/58

[58] Field of Search.....244/128, 30

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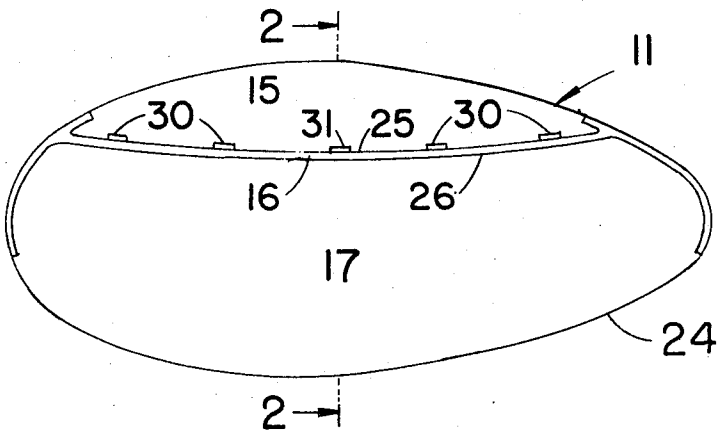
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Primary Examiner—Trygve M. Blix

[57] ABSTRACT

Passageways controlled by valves interconnect a permanent lifting-gas chamber with a high-altitude lifting-gas chamber that at low altitude may carry cargo gas, fuel gas, or ballast air. Once the high-altitude lifting-gas chamber is empty, the airship can ascend to high altitude, a portion of the lifting gas flowing from the permanent lifting-gas chamber to the high-altitude lifting-gas chamber; during descent, the transferred lifting-gas is returned to the permanent lifting-gas chamber.

20 Claims, 10 Drawing Figures



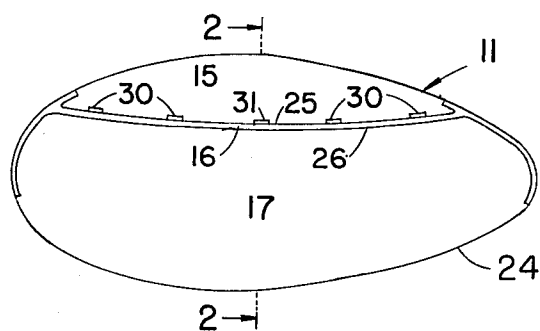


Fig. 1

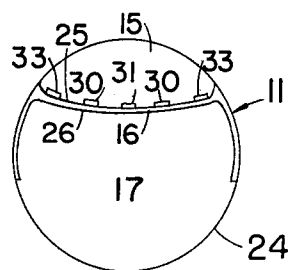


Fig. 2

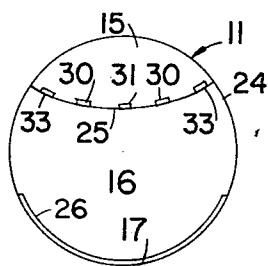


Fig. 3

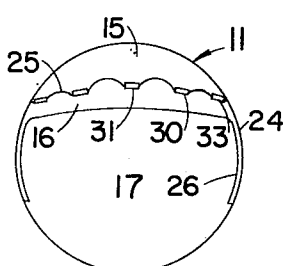


Fig. 4

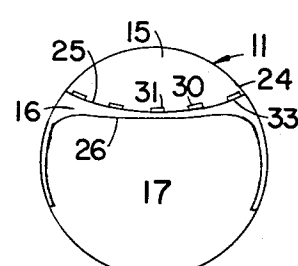


Fig. 5

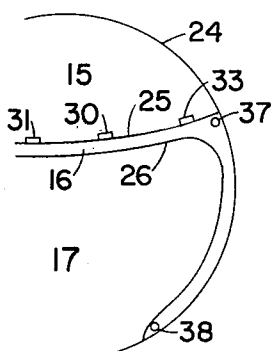


Fig. 6

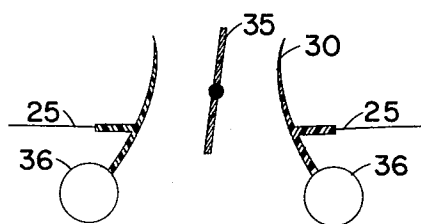


Fig. 7

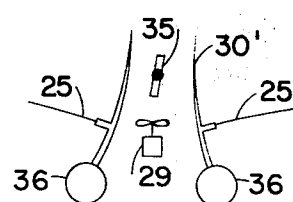


Fig. 8

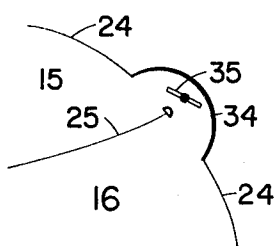


Fig. 9

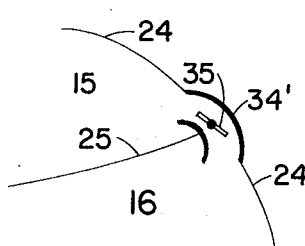


Fig. 10

AIRSHIP WITH INTERNAL TRANSFER OF LIFTING GAS

BACKGROUND OF THE INVENTION

1. Field of the Invention

Airship for carrying cargo gas and/or gaseous fuel at moderate altitude, with capability of flight at higher altitude when empty of cargo gas or gaseous fuel.

2. Description of the Prior Art

The rigid airship Graf Zeppelin carried fuel gas in bags disposed beneath the lifting-gas bags. The cargo-gas airship of U.S. Pat. No. 3,488,019 (Jan. 6, 1970; M. H. Sonstegaard; CARGO-GAS Airship with Boundary Layer Control) carries gaseous cargo in a cargo-gas chamber located below a lifting-gas chamber and above a ballast-air chamber.

The problem involved in the prior art, which is solved by the present invention, is that when the cargo-gas chamber or fuel-gas bags are empty, the altitude ceiling is limited by the size of the lifting-gas chamber or bags. If the maximum altitude capability is to be achieved on empty flight, the volumetric capacity of the lifting-gas chamber or bags must be sufficient to fill the airship and displace all the ballast air; provision of the requisite capacity in the lifting-gas chamber is costly and adds dead weight.

SUMMARY OF THE INVENTION

The present invention allows a cargo-gas airship to fly at higher altitudes when it is empty of cargo gas than when it is loaded therewith, even though the permanent lifting-gas chamber is sized only for the lower altitudes required for loaded flight. Empty return flights at high altitudes may be useful for taking short cuts across high mountain ranges, avoiding bad weather, utilizing favorable winds, or maintaining higher airspeeds made possible by the lower air densities that exist at the higher altitudes.

High-altitude capability on empty flights is obtained by transferring a portion of the lifting gas from the permanent lifting-gas chamber to the high-altitude lifting-gas chamber, these two chambers necessarily being sized, for the purpose of loading or unloading cargo gas, so as jointly to be capable of occupying all of the available volume inside the airship. One or more lifting-gas passageways, each fitted with a lifting-gas valve, interconnect the permanent lifting-gas chamber and the high-altitude lifting-gas chamber, allowing lifting gas to pass from the former to the latter chamber during ascent to high altitude and in the reverse direction during descent.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a section taken in the vertical longitudinal median plane of the airship, showing the airship at pressure height in the low-altitude mode, with the high-altitude lifting-gas chamber empty and the heaviest-gas chamber filled;

FIG. 2 is a view on section line 2—2 of FIG. 1 showing the airship in the same condition as in FIG. 1;

FIG. 3 is a view on section line 2—2 of FIG. 1 showing the airship at very high altitude, with the high-altitude lifting-gas chamber full of lifting gas and the heaviest-gas chamber empty;

FIG. 4 is a view on section line 2—2 of FIG. 1 showing the airship at very low altitude, with the high-altitude gas chamber almost empty and the heaviest-gas chamber almost full;

FIG. 5 is a view on section line 2—2 of FIG. 1 showing the airship at an altitude somewhat higher than that of FIG. 2;

FIG. 6 is a sectional view of a portion of the airship taken on line 2—2 of FIG. 1 and showing equipment for flushing and scavenging the high-altitude lifting-gas chamber;

FIG. 7 is a sectional view of a lifting-gas passageway provided with a lifting-gas valve;

FIG. 8 is a sectional view of the lifting-gas passageway provided with a lifting-gas valve and a blower;

FIG. 9 is a sectional view of an exterior lifting-gas passageway;

FIG. 10 is a sectional view of a semiexterior lifting-gas passageway.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIGS. 1 and 2 show a permanent lifting-gas chamber 15 in the upper part of the airship 11, a high-altitude lifting-gas chamber 16 in the middle, and a heaviest-gas chamber 17 at the bottom. The high-altitude lifting-gas chamber is separated from the permanent lifting-gas chamber above by the lifting-gas diaphragm 25 and from the heaviest-gas chamber below by the cargo-gas diaphragm 26. The permanent lifting-gas chamber 15 contains lifting gas at all times during normal operations. During loaded flight the cargo gas, if less dense than air, is carried in the high-altitude lifting-gas chamber 16 and ballast air in the heaviest-gas chamber 17; if the cargo gas is more dense than air it is carried in the heaviest-gas chamber, the necessary ballast air being carried in the high-altitude lifting-gas chamber. The cargo gas may be ordinary commercial cargo such as natural gas, or it may be gas carried partly or entirely for use as airship fuel.

If the airship 11 is employed to carry cargo gas that is less dense than air, then FIGS. 1 and 2 show the position of the cargo-gas diaphragm 26 after the cargo gas has been unloaded and the airship has risen to maximum altitude for the loaded mode of operation. In the loaded mode all of the lifting gas is contained in the permanent lifting-gas chamber 15. Maximum altitude in this mode is reached when the lifting-gas diaphragm 25 is bulging downward against the cargo-gas chamber to the maximum extent consistent with structural integrity.

Converting the airship to the high-altitude mode of operation requires the opening of the lifting-gas valve in at least one lifting-gas passageway 30 and allowing lifting gas to pass from the permanent lifting-gas chamber 15 into the high-altitude lifting-gas chamber 16. The airship can then gain altitude until the high-altitude lifting-gas chamber is filled with lifting gas and the heaviest-gas chamber 17 is emptied of ballast air, which is the condition shown in FIG. 3.

As the airship descends from its high-altitude flight, ballast air again fills the heaviest-gas chamber 17 and lifting gas returns, via the lifting-gas passageways, from the high-altitude lifting-gas chamber 16 to the per-

manent lifting-gas chamber 15. As the airship approaches low altitudes, a problem arises as the cargo gas diaphragm comes into contact, over an increasing area, with the lifting-gas diaphragm, for the lifting-gas passageways in the lifting-gas diaphragm tend to be closed off by the cargo-gas diaphragm.

If the airship can descend to the minimum altitude for which it was designed, the problem can be solved by the procedure illustrated in FIG. 4. Before the diaphragms make contact, all of the lifting-gas valves are either partially or entirely closed. The rising cargo-gas diaphragm, by pushing lifting-gas ahead of it, causes the lifting-gas diaphragm to bulge upward. This upward bulging keeps the central lifting-gas passageway 31 clear of the cargo-gas diaphragm until substantially all of lifting-gas has been returned to the permanent lifting-gas chamber, the last portion being returned via the central lifting-gas passageway, the gas being throttled through this passageway as necessary to maintain a gauge pressure across the lifting-gas diaphragm. The central lifting-gas diaphragm is placed so that it is in the vertical longitudinal median plane of the airship and at the uppermost point on the lifting-gas diaphragm when the latter is bulging upward.

In many practical cases it may be necessary to restore the airship to the low-altitude mode, i.e., to transfer the lifting gas in the high-altitude lifting-gas chamber to the permanent lifting-gas chamber, without bringing the airship down to its lowest design altitude. This transfer is shown taking place at a relatively low altitude in FIG. 4 and at a relatively high altitude in FIG. 5. If the altitude implied by FIG. 4 is the minimum altitude that can feasibly be reached, then the cargo-gas diaphragm cannot rise any higher and the lifting-gas diaphragm will have to fall to the cargo-gas diaphragm in order to complete the transfer of the lifting gas. The lifting-gas diaphragm will fall of its own weight, and because of the weight of the lifting-gas passageways, provided that the lifting-gas valves are open. The lifting-gas passageway 30 is shown in FIG. 7. It is attached to the lifting-gas diaphragm 25 and provided with a lifting-gas valve 35 and with passageway feet 36. As the lifting-gas diaphragm approaches the cargo-gas diaphragm, the passageway feet come into contact with the cargo-gas diaphragm. Gas flows between the passageway feet and upward through the lifting-gas passageways as the lifting-gas diaphragm approaches and then makes contact, over an increasing area, with the cargo-gas diaphragm. The passageway feet are rounded and smooth so that they will not damage the cargo-gas diaphragm. FIG. 8 shows a blower-boosted lifting-gas passageway 30', which is a lifting-gas passageway 30 modified to accommodate, and fitted with, a lifting-gas blower 29. The lifting-gas blower blows lifting-gas upward and makes possible faster transfer of the lifting gas from the high-altitude lifting-gas chamber to the permanent lifting-gas chamber after the cargo-gas diaphragm has reached its upward limit as determined by the minimum altitude of the airship.

When the lifting gas remaining in the high-altitude lifting-gas chamber is transferred back into the permanent lifting-gas chamber at a relatively high altitude, as illustrated in FIG. 5, the lifting-gas passageways are kept open as the airship descends. Flow through certain lifting-gas passageways tends to be cut off by the mu-

tual contact of the lifting-gas diaphragm and the cargo-gas diaphragm in the vicinities of the affected passageways. The first passageways to be so affected are those near the longitudinal median plane of the airship; the last affected are the flank lifting-gas passageways 33 (FIG. 5), which are located near the line of attachment of the lifting-gas diaphragm 25 to the airship envelope 24. By the time the flank lifting-gas passageways are seriously affected, practically all of the lifting gas has been transferred from the high-altitude lifting-gas chamber, and the airship is ready to be loaded with cargo gas.

Under some conditions it is desirable to flush remaining cargo gas from the high-altitude lifting-gas chamber 16 before transferring sizable quantities of lifting gas thereto. Such flushing minimizes the cumulative dilution of the lifting gas by cargo gas. Flushing is accomplished by discharging a relatively small amount of lifting gas from the central lifting-gas passageway 31 and from the lifting-gas flush manifolds 38 (FIG. 6) and exhausting the mixture of lifting gas and residual cargo gas via the scavenge-gas manifold 37. Each lifting-gas manifold 38 comprises a tube that has longitudinally spaced holes or perforations and that is supplied with lifting-gas from the lifting-gas chamber by suitable tube, valve, and blower means. The holes or perforations are small enough to throttle the flow of lifting gas and so provide an outflow that is approximately uniform throughout the length of the lifting-gas manifold. Each scavenge-gas manifold 37 comprises a tube having longitudinally spaced holes or perforations and provided with a blower for exhausting the gaseous mixture. If the lifting gas and cargo gases are combustible and not too valuable, the withdrawn scavenge gas may be stored in a fuel-gas ballonet and used for propulsion fuel.

FIG. 9 shows an exterior lifting-gas passageway 34 fitted with a lifting-gas valve 35 and connecting the permanent lifting-gas chamber 15 with the high-altitude lifting-gas chamber 16. Exterior lifting-gas passageways are highly accessible for repair and hence serve as emergency passageways when interior passageways fail safe in the closed position. Exterior lifting-gas passageways can also be installed as a supplement to, or as a substitute for, the flank lifting-gas passageways 33 and, indeed, can perform the functions of the other interior lifting-gas passageways with the possible exceptions of flushing and of returning lifting-gas to the permanent lifting-gas chamber under the conditions illustrated in FIG. 4. Where the conditions of FIG. 4 can be modified by rolling or pitching the airship sufficiently to bring the residual lifting gas that is trapped in the high-altitude lifting-gas chamber to the airship envelope 24, exterior lifting-gas passageways are capable of returning the lifting gas to the permanent lifting-gas chamber.

FIG. 10 shows a semiexterior lifting-gas passageway 34', which is a modification of the exterior lifting-gas passageway 34. The semiexterior lifting-gas passageway lies partly outside, and partly inside, the airship envelope 24. The semiexterior lifting-gas passageway does not protrude as far beyond the airship envelope as does the exterior lifting-gas passageway and yet is almost as accessible for maintenance and repair.

The exterior lifting-gas passageway and the semi-exterior lifting-gas passageway may be partly or entirely collapsible so that, when not in use, they may be flattened down to lie approximately flush with the airship envelope.

If the airship 11 is employed to carry cargo gas that is more dense than air, then at the completion of the unloading process the cargo-gas diaphragm 26 is at the bottom of the airship (as in FIG. 3), the heaviest-gas chamber 17 being empty and the high-altitude lifting-gas chamber 16 being filled with ballast air. If the airship is to be flown at an altitude that would cause the lifting gas to expand beyond the volumetric capacity of the permanent lifting-gas chamber 15 (i.e., in the high-altitude mode), the high-altitude lifting-gas chamber is first emptied and the heaviest-gas chamber simultaneously filled with air; this is preferably done while the airship is still on the mooring mast. If the lifting-gas is flammable, the residual air is purged from the high-altitude lifting-gas chamber with a gas that will not react dangerously nor form a combustible mixture with air or with the lifting gas. This is preferably done while the airship is on the mooring mast, the purge gas (e.g., nitrogen and/or carbon dioxide) being supplied from a land-based source and alternately injected, into the high-altitude lifting-gas chamber, via the port and starboard lifting-gas flush manifolds 38; the mixture of air and purge gas is alternately extracted via the scavenge-gas manifolds 37, the port scavenge-gas manifold working with the starboard lifting-gas flush manifold part of the time, and the starboard scavenge-gas manifold working with the port lifting-gas flush manifold the rest of the time. Upon completion of this purging process, the airship is ready to ascend to high altitude, the transfer, on ascent, of a portion of the lifting-gas to the high-altitude lifting-gas chamber, and the return, on descent, of the transferred lifting gas to the permanent lifting-gas chamber being accomplished in the manner described hereinabove in connection with an airship carrying cargo gas in the high-altitude lifting-gas chamber and ballast air in the heaviest-gas chamber.

I claim:

1. An airship having a permanent lifting-gas chamber separated from a high-altitude lifting-gas chamber by a lifting-gas diaphragm attached to the airship envelope along a line that is approximately horizontal and substantially symmetrical with respect to the vertical, longitudinal median plane of said airship, wherein the improvement comprises: at least one lifting-gas passageway interconnecting said permanent lifting-gas chamber and said high-altitude lifting-gas chamber; and valve means for permitting a sustained flow of lifting gas in either direction through said passageway.

2. The airship of claim 1 in which a scavenge-gas manifold is located inside and near the top of the high-altitude lifting-gas chamber and adjacent the airship envelope.

3. The airship of claim 1 in which at least a portion of a lifting-gas passageway is, during its operation, located outside the airship envelope.

4. An airship in which an approximately horizontal lifting-gas diaphragm that in each of its various normal positions is substantially symmetrical with respect to a vertical, longitudinal median plane forms a common boundary between a permanent lifting-gas chamber

above and a high-altitude lifting-gas chamber below, wherein the improvement comprises: at least one lifting-gas passageway located in said diaphragm; and valve means for permitting a sustained flow of lifting gas in either direction through said passageway.

5. The airship of claim 4 in which a lifting-gas passageway is located laterally in the vertical longitudinal median plane of said airship and longitudinally at the point on the lifting-gas diaphragm that is uppermost when said diaphragm is bulging upward.

6. The airship of claim 5 in which means are provided for holding the lifting-gas passageway out of contact with the cargo-gas diaphragm until substantially all lifting gas is returned to the permanent lifting-gas chamber, said means including: a lifting-gas valve located in the lifting-gas passageway and capable of throttling lifting gas; and a cargo-gas diaphragm.

7. The airship of claim 4 in which a scavenge-gas manifold is placed just below the junction of the lifting-gas diaphragm with the outer envelope.

8. The airship of claim 7 in which a lifting-gas flush manifold is located above the junction of the cargo-gas diaphragm with the airship envelope.

9. The airship of claim 4 in which the lifting-gas passageway is provided with a lifting-gas blower.

10. The airship of claim 4 in which the lifting-gas passageway is located in the vicinity of the junction of the lifting-gas diaphragm with the airship envelope.

11. The airship of claim 4 wherein a lifting-gas passageway is provided with passageway feet.

12. The airship of claim 6 in which a scavenge-gas manifold is placed just below the junction of the lifting-gas diaphragm with the outer envelope.

13. The airship of claim 12 in which a lifting-gas flush manifold is located above the junction of the cargo-gas diaphragm with the airship envelope.

14. The airship of claim 13 in which a lifting-gas passageway is provided with passageway feet.

15. The airship of claim 14 in which a lifting-gas passageway is provided with a lifting-gas blower.

16. The airship of claim 4 in which the lifting-gas diaphragm is provided with at least one flank lifting-gas passageway.

17. In an airship, a high-altitude lifting-gas chamber separated by a substantially horizontal permanent lifting-gas diaphragm from a permanent lifting-gas chamber above and by a cargo-gas diaphragm from a heaviest-gas chamber below, and means for transferring lifting gas from said permanent lifting-gas chamber to said high-altitude lifting-gas chamber and for returning lifting-gas to said permanent lifting-gas chamber, said means including: lifting-gas passageways for permitting sustained flow through the vicinity of the junction of the lifting-gas diaphragm with the airship envelope; and lifting-gas valves located in said lifting-gas passageways.

18. The airship of claim 17 in which at least one lifting-gas passageway is provided with a lifting-gas blower.

19. The airship of claim 17 in which the lifting-gas diaphragm is provided with a central lifting-gas passageway fitted with a lifting-gas valve.

20. The airship of claim 19 in which: a scavenge-gas manifold is placed just below the junction of the lifting-gas diaphragm with the outer envelope; a lifting-gas

flush manifold is located just above the junction of the cargo-gas diaphragm with the airship envelope; and there is at least one lifting-gas passageway fitted with a lifting-gas blower.

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