METHOD AND APPARATUS FOR OPERATING A TETHERED NATURAL SHAPE BALLOON TO, AT, AND FROM HIGH ALTITUDE

ABSTRACT: A tethered natural shape balloon is operated to, at and from a high altitude, i.e. 100,000 feet, by top-loading, rather than by conventional bottom-loading. A loading cable is attached at one end to a fitting at the inner top surface of the balloon and is attached at the other end to a remotely actuable motorized reel-and-brake assembly mounted on the top surface of a base plate. Other cables connect the bottom of the balloon to remotely actuable motorized reel-and-brake assemblies also mounted on the top surface of the base plate. The tether line is attached at one end by a fitting to the bottom surface of the base plate and is attached at the other end to a winch, which also serves as an anchoring means. As altitude and corresponding external pressure change, the configuration, i.e. volume and shape, is changed and controlled by paying out or reeling in the cables to prevent high and unequal stress of the balloon envelope material.
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BACKGROUND OF THE INVENTION

This invention relates to the control of the volume and shape of a natural shape balloon, and more particularly to a high altitude tethered natural shape balloon of the inverted type which is ideally suited for ascent to, float at, and descend from, in altitude of 100,000 feet above sea level.

The term "natural," as used herein in connection with the shape of a balloon, is intended to mean the shape of a balloon which is formed when the load of the tether line, i.e., of the payload is transferred to the buoyant lifting gas by means of a meridional (i.e. lateral) stress only. In other words, no circumferential stress exists.

The term "configuration," as used herein in connection with the shape of a balloon, is intended to include volume of the balloon. It is to be understood that the shape may change without a change in volume does not necessarily result in a change in shape.

Conventional methods and apparatuses for controlling the configuration of high altitude tethered balloons are of the bottom-loading type. That is, the load of the tether line, i.e. of the payload, is attached to the bottom of the balloon, and more accurately to the lower portion of the balloon structure. These methods and apparatuses include, among others, the use of elastic bands of a ballonet and of reefing bands. Elastic bands, i.e. bands of stretchable material, are integral to the balloon envelope and are not detachable from the balloon. A ballonet is in essence a balloon or an air cell within, i.e. internal of, the balloon envelope and the inflated volume of the ballonet is constant. Reefing bands are bands which are positioned on the external periphery of the balloon and are detachable or separable from the balloon by various means, such as a barometric switch. However, it is to be noted that as applied to the balloon art the term "reefing" is not limited to describing a type of configuration control band, but includes, in a broader sense, the reducing of the external surface of the balloon envelope such as by gathering, draping, grouping, folding and the like, of the excess balloon envelope material.

Regardless of the type or shape of the high altitude balloon, configuration control methods and apparatuses are of the utmost importance. This can be more readily appreciated if one realizes, for example, that in ascending from sea level to 100,000 feet, the volume of a balloon changes from approximately 8 times to 25 times the original volume at sea level and that, without configuration control, large deformations of the balloon envelope are very apt to occur, with resultant high and unequal stress of the balloon envelope material and possible balloon envelope tear or rupture and balloon failure.

It is fair and accurate to state that bottom-loading has not been sufficiently effective and has not been reliable enough to consistently effectuate configuration control of the balloon and to prevent balloon failure. This is particularly true when the balloon is descending and deflating and the loose excess balloon material is increasing in quantity external of the still inflated portion of the balloon envelope.

Our invention, by using top-loading, departs radically from conventional methods and apparatuses for controlling the configuration of high altitude tethered balloons during ascent, at float level, and during descent, and eliminates the disadvantages of bottom-loading. It thus constitutes a significant advancement over the present state-of-the-art.

SUMMARY OF THE INVENTION

Our invention pertains to a novel method of and a balloon apparatus for carrying aloft to a high altitude a load-bearing natural shape tethered, i.e. captive, balloon of the inverted type.

An object of this invention is to provide a method reliably carrying to an altitude of approximately 100,000 feet above sea level a natural shape tethered balloon of the inverted type, with attached tether line and other payload.

Another object of this invention is to provide apparatus for carrying a load-bearing natural shape tethered balloon of the inverted type to a high altitude.

Obviously, still another object of this invention is to accomplish effective configuration (i.e. volume and shape) control of the balloon from sea level to high altitude, at high altitude, and from high altitude to sea level.

A related object of this invention is to maintain symmetry of the balloon envelope, while the balloon structure is in operation, so as to minimize excess balloon envelope material that could pocket winds, cause overstressing of the material, and tear or rupture the balloon.

Another related object of this invention is to maintain excess balloon envelope material which is needed for expansion in a compact manner to eliminate unnecessary drag.

A further object of this invention is to achieve all of the foregoing objects, and others related thereto, by using top-loading, rather than the conventional bottom-loading, of the balloon envelope.

These and still other objects of this invention will become readily apparent after a consideration of the description of the invention and reference to the drawings.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side elevation view, in simplified schematic form, of a preferred embodiment of the invention, with the balloon envelope at sea level and prior to ascent; and
FIG. 2 shows a side elevation view, in simplified schematic form, of the preferred embodiment depicted in FIG. 1, but at float altitude of 100,000 feet.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In FIGS. 1 and 2, there is shown in simple schematic form a preferred embodiment of our invention at different altitudes but with the same reference characters in each FIG. denoting the same components.

More specifically, and with reference to FIG. 1, therein is shown at sea level and prior to descent a balloon envelope 11, which may be of the gored spherical shape but is, in this instance, of the cylindrical or slightly tailored cylindrical type with skin thickness being constant, although it could be of variable, stepped or tapered thickness with bottom opening 12, preferably circular in cross section. Balloon envelope 11 material is the lightweight flexible and gas-imperious, such as polyethylene film or "Mylar," a trademark of E.I. DuPont de Nemours and Co., Inc. for polyethylenene terephthalate resin film. Attached to opening 12 of balloon envelope 11 is a large diameter lightweight ring 13, such as of aluminum, with the mating periphery being gas-imperious. Attached to ring 13 and disposed vertically is one open end of cylindrical hollow member, membrane or sleeve 14, which is made of the same or similar, thin, lightweight, flexible and gas-imperious material as balloon envelope 11 and, although shown as cylindrical in form, sleeve 14 could be tapered downwardly. Clamping band or collar 15 of suitable material, such as aluminum, holds sleeve 14 in place and forms a gastight seal with ring 13.

Again with reference to FIG. 1, the top of balloon envelope 11 is shown as having been pulled or the like through opening 12 and bottom ring 13. A suitable fitting 16 is attached to the inner top surface of inverted balloon envelope 11 at the geometric, i.e., symmetrical, center thereof. A loading cable 17 is attached at one end to top-loading fitting 16 and is attached at the other end to a remotely actuatable motorized reel-and-brake assembly 18 which is affixed or otherwise mounted on the top surface of base plate 19. Outer cables, such as 20 and 21, disposed to either side of and essentially parallel to top-loading cable 17 and preferably totaling two on each side, are attached to individually fittings, such as 22 and 23, which in turn are attached to collar 15. The other end of each outer cable, such as 20 and 21, is attached to individual remotely actuatable motorized reel-and-brake assemblies, such as 24 and 25, which are also affixed or otherwise mounted on the top.
surface of base plate 19. Each of the reel-and-brake assemblies, such as 18, 24 and 25, have an amount of cable coiled and stored on the reel portion and a brake which can be applied to hold the reel in position. A tether line 26, preferably of stranded and tapered glass fiber, although it may be of steel or of nylon, is attached at one end to the bottom surface of base plate 19 by fitting 27 and is anchored at and coiled on ground winch 39, which is preferably powered and mobile and which pays out and reels in tether line 26 and, additionally, acts as an anchoring means. Also shown is buoyant gas supply unit 40.

With reference to FIG. 2, therein is shown the preferred embodiment depicted in FIG. 1, but at a float altitude of 100,000 feet. From an examination of FIG. 2, and a comparison with FIG. 1, it can be seen that balloon envelope 11 has expanded; that top-loading fitting 16 is in fact at the top of the inner surface of balloon envelope 11; and that top-loading cable 17 has been payed out through sleeve 14 and into balloon envelope 11. Cables, such as 17, 20 and 21, are taut with one end attached to the appropriate respective fitting, such as 16, 22 and 23, and with the other end coiled and stored on the appropriate respective reel-and-brake assembly, such as 18, 24 and 25 which in turn are mounted on base plate 19. Tether line 26 is in an extended mode, with fitting 27 attaching it at one end to base plate 19 and with ground winch 30 anchoring it at the other end.

With reference to both FIGS. 1 and 2, the primary purpose of sleeve 14 is to permit control and development of super pressure within balloon envelope 11.

Also with reference to both FIGS. 1 and 2, and the preferred embodiment shown therein, it is to be noted that we have reference in describing the embodiment of a top-loaded balloon envelope 11 which when at float altitude of 100,000 feet will have a cubic foot volume of approximately 30,000,000; and the tether line of which will be approximately 130,000 feet long and where the ground winch 30 will have a pay out rate of approximately 2,000 feet per minute and a reel in or pay in rate of approximately 200 feet per minute.

However, not shown in the drawings, in order not to unnecessarily encumber them are suitable means for sending desired command signals to motorized reel-and-brake assemblies, such as 18, 24 and 25.

MODE OF OPERATION OF THE PREFERRED EMBODIMENT

Balloon envelope 11 is inflated by suitable means 40, FIG. 1, with a bubble of predetermined quantity of helium, the lifting gas.

After inflation with the helium bubble, and before launch, the embodiment is as shown in FIG. 1 with the excess balloon envelope 11 material being disposed essentially between top-loading fitting 16 and bottom ring 13, internal of sleeve 14.

After launch, and during ascent, as altitude increases and external pressure decreases, the helium expands filling balloon envelope 11 and pulls top-loading cable 17 which in turn is payed out from reel-and-brake assembly 18.

As a result, the top of balloon envelope 11, FIG. 1, is in a downwardly position and top-loading fitting 16, FIG. 1, and a portion of top-loading cable 17, FIG. 1, are pulled up or the like through sleeve 14 and bottom ring 13.

Concurrently, tether line 26 is payed out from ground winch 30, FIG. 1, until balloon envelope 11 attains the desired altitude which in this instance is 100,000 feet. Deployed balloon envelope 11, at equilibrium float altitude, is as shown in FIG. 2.

In the event either that a particular change is desired in configuration, such as to obtain a more nearly symmetrical shape or to make a change in volume, or that a change is desired from top-loading to bottom-loading for some reason such as to reduce drag, then other cables, such as 20 and 21, FIG. 2 and if need be pay loading cable 17, FIG. 2, are payed out or reeled in, as applicable, by remote control such as a command signal from a ground based station.

It is to be noted that a minor super pressure may develop within balloon envelope 11, FIG. 2, at any altitude, as a result of the top-loading configuration. Super pressure may also develop near float altitude as a result of volumetric limitations of the balloon envelope 11 material. Therefore, sleeve 14 is furnished to control the effects of the super pressure by permitting the helium to be displaced or "pushed," so to speak, by the super pressure into sleeve 14, until the ambient pressure external of the balloon equals or is less than the pressure within balloon envelope 11, FIG. 2, and the helium may rise and return back into balloon envelope 11.

Retrieval, i.e. reelin in, is accomplished essentially by reversing the procedure of launching the balloon.

While there has been shown and described the fundamental features of our invention, as applied to a preferred and particular embodiment, it is to be understood that this is by way of illustration only and is not intended as a limitation, and that various substitutions and omissions may be made by those skilled in the art without departing from the spirit of the invention.

For example, rollers, or the like, may be disposed at the inner perimeter of and be made integral to bottom ring 13, FIGS. 1 and 2, to allow excess balloon envelope 11 material, FIG. 1, to pass through ring 13 easier and quicker; means may be provided, so that during retrieval a portion of the lifting gas may be valved by a remote control command signal to facilitate deflation of the balloon and to facilitate recovery; and, if desired, an over simplified but effective embodiment of the invention could be made by eliminating the outer cables, such as 20 and 21, and fittings, such as 22 and 23, and reel-and-brake assemblies, such as 18, 24 and 25, and having a top-loading cable 17 of predetermined length extend from fitting 16 through base plate 19 and connect to tether cable 26.

We claim:

1. An apparatus for operating a tethered natural shape balloon of the inverted type to, at, and from high altitude, comprising a combination:
   a. a natural shape balloon envelope of a thin, lightweight, flexible and gas-impermeable material, with said balloon envelope having an opening at its bottom, and containing a predetermined quantity of lifting gas;
   b. open ended hollow member, disposed vertically and substantially greater in length than in width, of a thin, lightweight, flexible and gas-impermeable material, with the upper of the open ends of said hollow member mating and forming a gas tight seal with the periphery of the opening at the bottom of said balloon envelope;
   c. a loading cable attached, at one end, to the geometric center of the inner top surface of said balloon envelope, with said loading cable extending internal of said balloon envelope and passing through the bottom opening of said balloon envelope and into and through said open end hollow member and extending below the lower open end of said hollow member;
   d. a tether line attached at one end to the other end of said loading cable; and
   e. means for paying out and reelin in said tether line, the other end of which is attached to said means, with said means also serving to act as the anchoring for said balloon envelope.

2. The apparatus as set forth in claim 1 wherein said tether line is of glass fiber, stranded and tapered.

3. The apparatus as set forth in claim 1 wherein a base plate having a top surface and a bottom surface is interposed between said loading cable and said tether line at their point of attachment, with said base plate having:
   a. a fitting at its bottom surface to which one end of said tether line is attached;
   b. a plurality of remotely actuable motorized reel-and-brake assemblies mounted on its top surface, with one end of said loading cable attached to one said remotely actuable motorized reel-and-brake assemblies which is located below and external of the lower open end of said hollow member, with that said remotely actuable reel-and-brake assembly being capable of paying out and reelin in said
loading cable upon command signal from a remote location; and
c. cables attached at one end to said other remotely actuatable motorized reel-and-brake assemblies mounted on the top surface of said base plate, with the other end of each said cable attached to the external surface of said balloon envelope near the mating periphery of the bottom opening of said balloon envelope and the upper of the open ends of said hollow member, with other said reel-and-brake assemblies being capable of paying out and reeling in said cables upon command signal from a remote location.

4. The method of operating and controlling the configuration, from sea level to, at, and from high altitude, of an inflated, tethered, inverted natural shape balloon having an envelope of thin, lightweight, flexible, gas-impermeable material, a bottom opening in said envelope, and an open ended vertically disposed hollow member, of the same material as the balloon envelope, the upper end of which attached in gas-impermeable manner to the bottom opening, comprising the steps of:
   a. attaching one end of a loading cable to the inner top surface of the balloon envelope, with the cable extending from its point of attachment through the bottom opening of the balloon and into, through and out of said hollow member;
b. attaching the other end of the loading cable to a motorized remotely actuatable reel-and-brake assembly which is capable, upon receipt of a command signal from a remote location, of paying out and reeling in the loading cable;
c. mounting the reel-and-brake assembly on the top surface of a base plate having a top surface and a bottom surface;
d. attaching one end of a tether line to the bottom surface of said base plate;
e. attaching the other end of the tether line to a powered ground winch;
f. paying out and reeling in the tether line from the ground winch to attain ascent, equilibrium float altitude, and descent of the balloon; and
   g. paying out and reeling in the loading cable to obtain and to maintain the desired configuration of the balloon.

5. The method as set forth in claim 4 comprising the additional steps of:
   a. attaching one end of each of plurality of cables, external of the balloon envelope and of the hollow member, to the external surface of the balloon envelope near the mating periphery of the bottom opening of the balloon envelope and the upper of the open ends of the hollow member;
b. attaching the other end of each cable to a separate one of a plurality of motorized remotely actuatable reel-and-brake assemblies which are capable upon receipt of a command signal from a remote location of paying out and reeling in each cable;
c. mounting the plurality of motorized remotely actuatable reel-and-brake assemblies on the top surface of the base plate at positions where each cable will be essentially parallel to each other and to the loading cable; and
d. paying out and reeling in at least one such cable to assist in obtaining and to assist in maintaining the desired configuration of the balloon.