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L. S. BOHL ETAL

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AUTOMATIC LIFT AUGMENTATION FOR BALLOONS

Filed Aug. 4, 1959

2 Sheets-Sheet 1

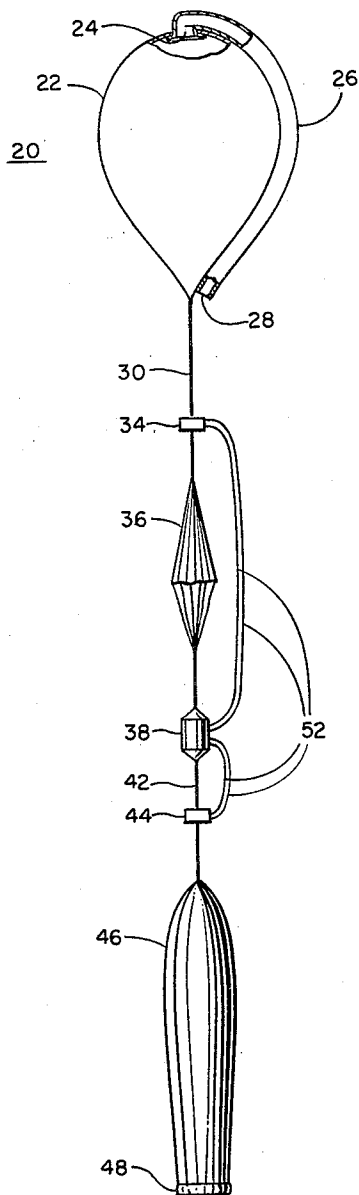


FIG. 1

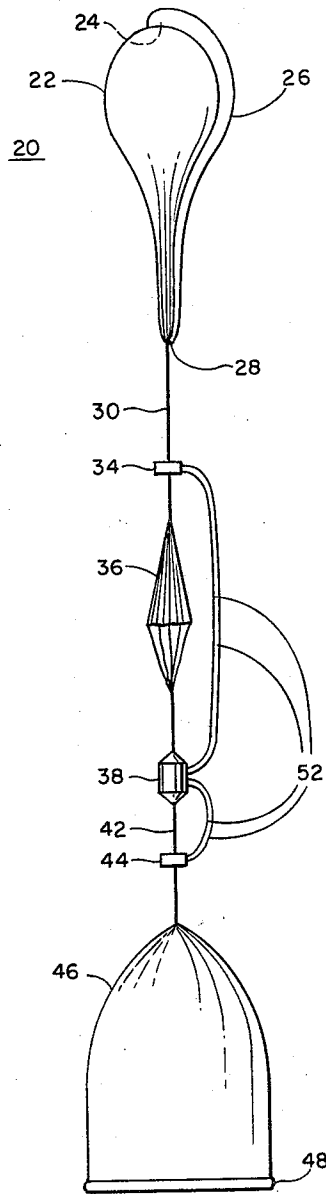


FIG. 2

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FIG. 3

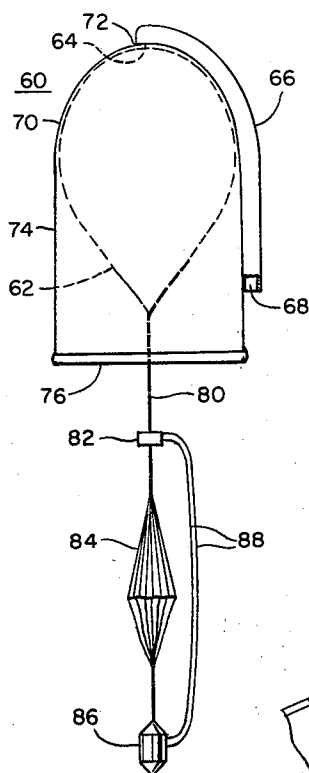


FIG. 4

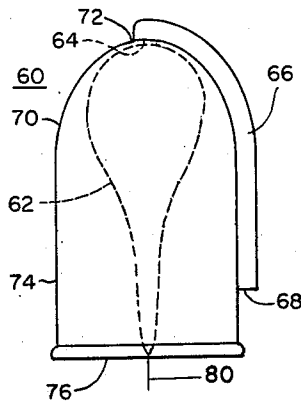


FIG. 5

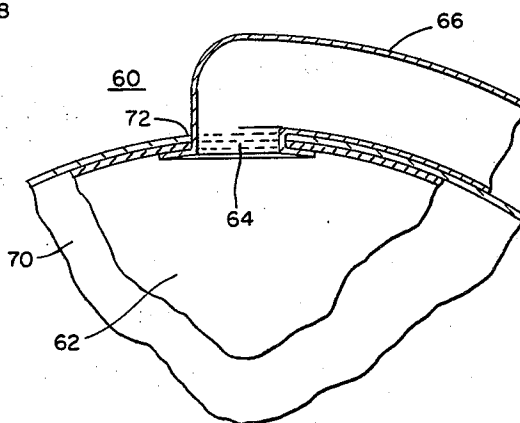
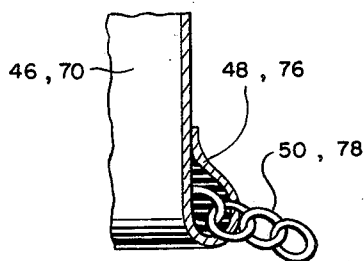


FIG. 6



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AUTOMATIC LIFT AUGMENTATION  
FOR BALLOONS

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8 Claims. (Cl. 244-96)

This invention relates to balloons and is concerned more particularly with prolonging high altitude balloon flight.

An object of the invention is to provide a balloon system which will recover lift equal to sunset loss of lift without necessitating ballasting.

Another object is to provide a balloon system which will intake air without mixing it with the lift gas and will discharge air to the extent necessary to maintain constant lift.

A further object is to provide a balloon system which will repeatedly reascend substantially to original ceiling altitude with substantially reduced expenditure of ballast.

It is also an object of the invention to provide a balloon system using air unmixed with lift gas to compensate for sunset loss of lift and will intake and valve such air without the aid of pumping apparatus or the like.

Further objects and advantages of the invention will appear as the description proceeds.

The invention will be more readily understood on reference to the following description and the accompanying more or less schematic drawings, wherein:

FIG. 1 shows a balloon system including a canopy suspended below the balloon in accordance with one form of the invention, with the system at ceiling altitude so that the balloon is substantially full and the canopy slightly inflated with atmospheric air.

FIG. 2 is similar to FIG. 1 but shows the system at a substantially lower-than-ceiling altitude, so that the balloon is partially collapsed and the canopy is substantially full of atmospheric air.

FIG. 3 is similar to FIG. 1 but shows a canopy in the form of a shroud about the balloon.

FIG. 4 shows the balloon and shroud of FIG. 3 at a substantially lower-than-ceiling altitude.

FIG. 5 is an enlarged sectional view showing the tops of the balloon and shroud and the connected end of the duct.

FIG. 6 shows the weighted hem structure of either canopy.

With the onset of sunset, a balloon undergoes loss of solar radiation and hence loss of lift, and the balloon descends.

The open-bottom high altitude balloon having a ceiling altitude on the order of 100,000 feet and upward, with its large ground-to-ceiling lift gas volume expansion ratio on the order of 100 to 1 or greater, has the potential of doubling the gross weight of the balloon system every 15,000 to 20,000 feet of descent, merely by taking in sufficient air in descent to maintain its ceiling volume. Thus, notwithstanding loss of lift gas by diffusion and leakage, the gross weight of the balloon system after a considerable descent may be a large multiple of the original gross weight, and any increase in temperature of the gas and contained air, relative to the temperature of the outside air, has the effect of increasing the lift by an amount proportional to the new gross weight, so that a small increase in temperature at a lower-than-ceiling altitude can result in an added lift which can offset the loss of lift resulting from a greater drop in temperature which the system experienced at ceiling altitude at sunset. For example, if a 300-lb. gross weight open-bottom bal-

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loon system at ceiling altitude were to undergo a 5% (15 lb.) sunset loss of lift and the system were to descend say 65,000 feet to an altitude where the pressure is five times as great as at ceiling, and consequently the increased gross weight due to air intaken to maintain the balloon full is substantially five times as great as at ceiling, a net warming of 1% with the new gross weight (1500 lb.) would produce a lift of 15 lb., which would stop the descent of the system at such lower altitude.

With the next sunrise, the balloon will climb, but, because the intaken air is denser than the lift gas, and the gas has been diluted somewhat by the intaken air, and some gas is lost with air by valving during the climb and some gas may have been lost by diffusion and leakage, the climb will stop at a lower-than-ceiling altitude. Open-bottom balloons have been observed to float three or four days in this manner. Each succeeding day, as the gross weight of the system increases, the sunset loss of lift becomes proportionately greater, requiring more lift from intaken air to achieve stability, i.e., check the descent at an altitude above ground. Altitude stability in successive cycles in accordingly achieved at successively lower altitudes, until finally the lift necessary to sustain flight can no longer be obtained from the environment of the balloon, with the result that the descent continues to the ground.

In addition to suffering temporary losses of lift, due to sunset and other changes in radiation environment, a balloon may also undergo permanent losses, through leakage and diffusion of the lift gas through the balloon fabric. In the case of an open-bottom balloon, further permanent loss of lift occurs as noted above.

One method of coping with temporary as well as permanent loss of lift is to drop ballast. This process is irreversible, however, in that the ballast cannot be retrieved for future use on the same flight. The ballast dropped each time reduces by that much the gross weight of the balloon system, with the result that the system at the next sunrise tends to ascend to an altitude higher than its initial ceiling altitude, and valves gas until the system is stabilized at its initial ceiling altitude, where the total lift equals the new (decreased) gross weight. Since the amount of ballast dropped each nighttime is a certain fraction of the running gross weight, the quantity of ballast required for a flight of several nights' duration is compounded so that the limit of duration of the flight is approached quite rapidly in practice. For example, at an 8% per day loss of lift, in say a 14-day flight, the ballast at launching must be about 3.3 times the final gross weight, a most objectionable situation from a practical standpoint when it is considered that the final gross weight includes the weight of the balloon, ballast container, gondola, and telemetering and/or other instrumentation. The total amount of gas valved for this example would be equivalent to that capable of increasing the ceiling altitude by 30,000 feet.

Altitude stability of a balloon system is affected by the temperature field in the atmosphere. This field can be represented by altitude profiles of the daytime and nighttime superheat.

As noted above, the open-bottom balloon system uses intaken air to promote altitude stability, the temperature field acting on the air to impart lift. Because of the mixing of the air with the gas, the open-bottom balloon, as noted above, leaves much to be desired.

The present invention takes advantage of the lift augmentation afforded by intaken air, without the attendant disadvantages, intaken air being expelled without gas valving, and ballasting dispensed with, or resorted to only to compensate for the relatively small amount of gas which may be lost permanently through diffusion and leakage of lift gas through the balloon fabric. The loss

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through diffusion is negligible, and the loss through leakage per day will vary from balloon to balloon and may average about 2 or 3%.

There are provided in accordance with the invention balloon systems which include a container constructed and arranged to intake (and discharge) air in sufficient quantities to compensate for sunset loss of lift, without danger of mixing the lift gas with the air, and with either no ballast or only enough ballast to compensate for the generally relatively small permanent loss of gas by diffusion and leakage through the balloon.

A balloon system according to one form of the invention is shown at 20 in FIGS. 1, 2 and 6, and comprises a balloon 22 which is closed except for a top opening 24 leading to a duct 26 which extends down along and is attached to the outside of the balloon. The duct 26 is open at the bottom 28 so that lift gas can be valved but air cannot enter the balloon. The length of the duct 26 may be selected to terminate at the desired level and thus determine the ceiling altitude of the balloon. A load line 30 hanging from the balloon 22 passes through a cutter 34 and suspends a parachute 36 supporting a gondola 38 carrying the payload. A line 42 extending from the gondola 38 passes through a cutter 44 and suspends an inverted bag or canopy 46 whose hem 48 is weighted as by a chain 50. The gondola carries batteries and switches for actuating the electrically-fired cutters 34 and 44.

The total lift is at all times almost precisely equal to the total weight of the system, the only difference being insignificant at altitudes upwards of 50,000 feet and being due to aerodynamic drag and extremely light accelerating forces.

When the system 20 is at ceiling altitude, the balloon 22 is fully inflated. On the first ascent, the canopy 46 is substantially collapsed; at ceiling it will expand gradually and raise the ceiling slightly. At sunset the system 20 starts to descend and more air enters the canopy 46 with the increasing atmospheric pressure. Thermodynamic drag warms and therefore imparts lift to the air in the canopy, the lift force acting against the inside surface of the canopy to increase the volume of the canopy, causing more air to be intaken and the lift due to the air in the canopy to increase further, slowly decelerating the system. The increased intaken air with descent also undergoes thermal compression which adds to the lift.

Before the canopy 46 is substantially full, the lift varies as the third power of the product of the superheat and the density. When the canopy 46 is substantially full, the lift varies directly as the product of the superheat and the density. The canopy 46 is of such size that the system 20 can achieve altitude stability, provided the superheat is positive, by descending to an altitude at which the air is of sufficient density to insure the desired lift augmentation.

Similarly, whatever lift is gained by sunrise is lost by reason of loss of lift through discharge of warmed intaken air in ascent.

A practical ratio of diameter to collapsed length for the canopy 46 is 3/4. A canopy 46 having such a configuration, with a hem 48 relatively very slightly weighted as by a chain 50 for hem stability, will fill when the lift (due to the superheated contained air) is slightly less than 1/5 of the weight of the canopy and will become unstable, or tilted, at a lift which is approximately 0.5 to 0.6 of the weight of the canopy. The fact that the warmed contained air overcomes a part of the weight added by reason of the canopy is an underlying factor in the advantage gained by the use of the canopy.

As noted above, permanent losses of lift can be compensated for only by ballasting. If not compensated for, permanent losses of lift will result in slight depression of ceiling altitude.

In order for the lift augmentation to take place in accordance with the invention, there must be present a positive superheat region for static stability, which is

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found more frequently in the summer than in other seasons at latitudes of about 45°, or is found substantially throughout the year under substantially more tropical conditions. Ballast should be provided for those nights when ample superheat to sustain flight is not present. The daytime ceiling altitude should be sufficiently high in the stratosphere that at night the system can descend to altitudes where warming is most likely with enough air intaken to regain the sunset loss of lift.

At sunrise, if still air borne, the system has free lift and starts to climb. With any increment of increased altitude, some of the warmed air which was contributing to the lift is valved (i.e., flows) out of the bottom of the filled-out canopy, the remaining contained air then requiring a higher superheat in order to maintain its contribution to the climbing lift. Such added superheat is acquired slowly, so that the approach to ceiling is slow, sometimes extending over several hours.

The sum of the lifts contributed by the balloon gas and the canopy air must equal the gross weight of the system to insure altitude stability. The balloon and canopy lifts under both daytime and nighttime conditions can be predetermined to insure that the sunset loss of lift suffered by the balloon gas and canopy air is made up by the daytime lift of the gas and particularly the canopy air, which air will compensate for most of the sunset losses, without causing the canopy to tilt. Any permanent balloon loss of lift, as by diffusion and leakage, not compensated for by ballast, will have to be assumed by the canopy. These limitations, together with the fact that the range of altitudes and superheats with which one must contend for high altitude balloon flights is fairly well established, will determine the range in size of a canopy for a given balloon and load. For example, for a 250,000 cu. ft. polyethylene balloon carrying a 100 lb. payload, experience indicates that the minimum size canopy should have substantially the same collapsed length as the balloon in order that altitude stability may be expected, and, with a canopy capable of three times such minimum volume, the daytime lift and sunset effect will increase to the point where nighttime lift due to the canopy is near maximum without tipping of the canopy.

The cutters 34 and 44 are connected by wiring 52 to switches and batteries (not shown) housed in the gondola 38, the switches being timed (or ground-radio-controlled) so that the canopy is released first (by the firing of the cutter 44) so that it will not foul the parachute 36 when the load is cut from the balloon by the firing of the cutter 34.

A modified balloon system is shown at 60 in FIGS. 3 to 5, and comprises a balloon 62 closed except for a top opening 64 leading to a duct 66 open at its bottom 68, and a canopy 70 serving as an envelope or shroud for the balloon and connected at 72 to the balloon top about the opening 64, and otherwise unconnected to the balloon, the duct extending down and being connected to the outside of the shroud. The shroud configuration is such that when the balloon 62 is fully inflated (FIG. 3) the upper part of the shroud 70 conforms to the crown of the balloon and the remainder 74 of the shroud hangs as a cylinder from the balloon equator. For hem stability, the hem 76 of the shroud is weighted, as by a chain 78. A load line 80 hanging from the balloon 62 passes through an electrically-fired cutter 82 and suspends a parachute 84 which in turn suspends a gondola 86 housing a battery and switch (not shown) and from which extends wiring 88 to the cutter.

The launching of a shroud-balloon system is like that of an ordinary balloon system, the shroud adding nothing but its weight to the field operation procedures. Unlike the canopy 46, the shroud 70 at ceiling altitude (FIG. 3) is fully open. At lower altitudes the behavior of the shroud 70 is similar to the behavior of the canopy 46.

The weight of displaced ambient air is of course also equal to the product of the ambient air density and the

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total volume of the shroud. That volume will in general depend on the size of the balloon and on the lift contributed by the air contained in the canopy, that lift being proportional to the product of the air pressure and the superheat.

Using a shroud 70 whose collapsed length is equal to that of the balloon 62, the volume of air in the shroud at ceiling altitude is about 0.9 times the volume of lift gas in the filled balloon 62. In this case it is apparent that the shape of the shroud is independent of the value of  $p\theta$ , where  $p$  is the pressure, usually expressed in millibars, and  $\theta$  is the superheat, usually expressed in °C.

The size of the balloon gas bubble of course varies with altitude, and one might expect the shroud shape to vary accordingly. This would indeed be true if the  $p\theta$  values were very much smaller than 400 mb.°C. for a balloon system whose shroud and balloon are of the same collapsed length. But substantially higher values of  $p\theta$ , on the order of several hundred mb.°C., are sufficient to push out on the shroud, as the system descends and rises after the initial rise to ceiling altitude, to such an extent that a large lower part of the shroud takes the form of a right cylinder, and the  $p\theta$  values encountered in high altitude balloon flights up to and beyond 100,000 feet are ample for that purpose. Indeed a large part of the range of  $p\theta$  values can be ignored, since the system tends to move in such a way as to keep the same value of  $p\theta$ , which value is established at ceiling and, in a typical case, might be (25 mb.)(16° C.)=400 mb.°C.

Shroud shapes can be calculated by forward integration of the appropriate differential equations, which are obtained by considering the forces of gravity, pressure, and tension acting on the shroud fabric. In making the integration, one must choose the proper initial conditions to insure that the solution represents a shroud of the proper collapsed length, that is, one must solve an Eigenvalue problem for each value of  $p\theta$ .

A suitable balloon-shroud design would be one, for example, in which the balloon and shroud are each made of 1-mil polyethylene having a collapsed length of 120 ft., using a 20-lb. hem chain.

The net lift of a balloon system due to superheat can be expressed in terms of buoyancy potential, and a balloon system is said to have zero buoyancy potential when the superheat is zero. In the case of a balloon system which relies solely on lift gas to provide lift, and where no lift gas is valved, and assuming no loss of gas by diffusion and leakage, the buoyancy potential  $P_g$  due to the gas can be expressed by the equation

$$P_g = M\sigma \frac{\theta}{T}$$

where  $M$  is the constant weight of the gas,  $\sigma$  is the constant ratio of the molecular weight of atmospheric air to the molecular weight of the gas,  $\theta$  is the gas superheat, and  $T$  is the absolute temperature of the ambient air. If the superheat at a high altitude is less than at some lower altitude, the balloon will stabilize before reaching the ground. However, daytime superheat is usually greater than nighttime superheat at any level down through the atmosphere, so that there usually is no chance for such a balloon to keep from descending to the ground at night in the absence of some means for augmenting the gas lift.

If the system included, in addition to a balloon which does not valve gas, a container for intaking air which cannot mix with the gas, then the buoyancy potential  $P_a$  due to superheated contained air can be expressed by the equation

$$P_a = A \frac{\theta}{T}$$

where  $A$  is the weight of the contained air and, of course, will not be constant. The superheat for the lift gas and the superheat for the contained air are normally substan-

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tially equal, so that the total weight  $G_t$  of displaced ambient air can be written

$$G_t = M\sigma + M\sigma \frac{\theta}{T} + A + A \frac{\theta}{T} = (M\sigma + A) \frac{T + \theta}{T}$$

Transposing,

$$A = G_t \frac{T}{T + \theta} - M\sigma$$

The total net lift of the system is

$$G_t - M - A - W = G_t \frac{\theta}{T + \theta} + M(\sigma - 1) - W$$

where  $W$  is the dead weight of the system. Since, by definition, buoyancy potential is that portion of the net lift which is due to superheat, the buoyancy potential  $P$  of this gas-air system is

$$P = G_t \frac{\theta}{T + \theta}$$

Since  $\theta$  is so small compared to  $T$ , the denominator can be taken as  $T$  to simplify computation.

The last equation is equally true for both forms of the invention notwithstanding that, in the shroud system, the balloon is affected by the shroud-contained air in which the balloon floats, and the varying size of the balloon with different altitudes is accompanied by oppositely varying volume of shroud-contained air.

The superheat profile for a bare balloon consists of a day curve and a night curve, and of course is a property of the balloon material and of the radiation conditions in the atmosphere, and would be expected to vary from day-to-day, depending on atmospheric conditions. The night superheat profile might be expected to show seasonal variation, with positive nighttime superheats appearing frequently only in the summer (at other than substantially tropical regions). The superheat profile (which will be the same for all systems made of the same balloon material and operating in the same atmosphere) should be distinguished from the buoyancy potential profiles since buoyancy potential is a property of the particular balloon system and is independent of atmospheric conditions. Although the un-canopied balloon system at ceiling at night can gain buoyancy potential by descending, it can never gain all of the lift lost at sunset (i.e., lost in undergoing the change from day superheat to night superheat). Apart from the effect of aerodynamic drag, however, the balloon will never change its buoyancy potential. Instead, at sunset, for instance, the balloon will merely descend at a rate sufficient to develop a "thermal drag" superheat large enough to restore the buoyancy potential to its daytime value. The superheat profiles apply only to non-moving situations, i.e., do not take into consideration temperature changes due to drag.

The buoyancy potential for a shrouded balloon is quite different from that for a bare balloon. Since the volume of the shroud is constant, the weight  $G_t$  of the displaced ambient air is proportional to the pressure altitude  $p$ , and the buoyancy potential

$$(P = G_t \frac{\theta}{T})$$

of the system will then be just proportional to the product  $p\theta$ . The shrouded balloon can easily go from day superheat to night superheat by a small descent at constant buoyancy potential.

There may be some nights when the superheat profile is not positive at any altitude, and under this condition the shroud will contribute nothing in the way of static stability. It is possible that, even on a night with an all-negative superheat profile, the descent might cause enough thermal-drag-warming of the air in the shroud to fill out the shroud, thus contributing a very large thermal drag force to the system. If the descent rate could be slowed enough, of course, the system would still be air-borne at sunrise.

A moving balloon system may be said to move at sunset or sunrise along a line of constant buoyancy potential from day to night or vice versa. For a bare balloon system this means that the balloon tends to keep the same value of the superheat,  $\theta$ , whereas for a shrouded balloon it is the  $p\theta$  value which tends to remain constant. Thus, after sunset, a bare balloon, if still airborne, will remain aloft at an altitude (if there is one) where the nighttime superheat is equal to the ceiling daytime superheat. A shrouded balloon system will descend at sunset to the level (if any) where the nighttime value of  $p\theta$  is equal to the daytime ceiling value of  $p\theta$ . A ballast drop in either system will lower the buoyancy potential of the system.

The response of a balloon system to the dropping of an increment of ballast is a convenient indication of the stability of the system. The response can be expressed as the fractional decrease in pressure altitude per unit weight of ballast dropped. The smaller the response, the greater the stability.

The ballast responsiveness of a bare balloon floating below its ceiling altitude will depend on the superheat profile of the atmosphere. In most cases, however, a small ballast drop is sufficient to send the balloon all the way back up to ceiling, so that the system has little stability.

In the case of the shrouded balloon, the buoyancy potential profiles for the same superheat profile condition have a substantial slope, so that, if the superheat profile is very nearly along a line of constant superheat, the ballast responsiveness will be

$$\frac{\Delta p/p}{\Delta B} = \frac{1}{P}$$

where  $\Delta p/p$  is the fractional change in pressure altitude as a result of a ballast drop,  $\Delta B$ , and  $P$  is the buoyancy potential.

It is usually not necessary to drop sunset ballast on shroud flights, because the same buoyancy potential will likely exist at some lower altitude to stop the descent. The last equation therefore shows that a shrouded balloon system has the same ballast responsiveness, day or night. Of course, it is possible that the day and night superheat profiles will not have exactly the same slope, and in such a case the last equation would not strictly hold. Another limitation to the use of that equation is that the air under the shroud may not have the same superheat from top to bottom of the shroud. If, for instance, the air near the bottom of the shroud had less superheat than the rest of the air in the shroud, the system would have to rise further in order to valve heated air lift equal to the ballast drop, with the result that the ballast responsiveness would be greater than in the case of a constant superheat distribution within the shroud.

The important conclusion to be drawn from the calculation of shroud shapes and volumes is that even with modest superheats a shroud remains fully open even though the balloon therein will be small at the lower altitudes, so that the flight characteristics of a shrouded balloon are strikingly different from those of a bare balloon. An unballasted shrouded balloon may be thought of as having a "day" ceiling altitude and a "night" ceiling altitude. One would expect a fairly definite day altitude with some variability in the night altitude (particularly in the winter when at times there may be no lower altitude at which the needed buoyancy potential exists). For purposes of prolonged flight, it might be necessary to provide a ballast drop for some nights as the only means of preventing descent to the ground. Even then, the saving on ballast (and hence the reduction in the gross weight of the system) will be quite substantial, since even in a case where some ballast must be dropped some nights, the amount of ballast dropped will be substantially less than that required for a bare balloon, representing a permanent and substantial ballast saving.

In the foregoing discussion a particular shroud was

used as an example, and it was found that this shroud would be substantially fully open when  $p\theta$  is larger than a certain value  $(p\theta)_{\min} = 400 \text{ mb.}^\circ \text{C.}$

A shroud with a different collapsed length and different weight would require a different minimum  $p\theta$  to substantially completely fill out the shroud. This value  $(p\theta_{\min})$  is a function only of the weight of the shroud itself and the collapsed length of the shroud.

In computing a shroud shape and volume, it is found that the only significant parameter is the dimensionless number

$$\frac{\beta D^3}{S}$$

where  $\beta$  is the lift per unit volume of the air in the shroud,  $D$  is the collapsed length of the shroud, and  $S$  is the weight of the shroud itself. The value  $\beta$  is proportional to  $p\theta$  and thus the shape of a shroud is completely determined by the number

$$p\theta \frac{D^3}{S}$$

For any shroud

$$(p\theta)_{\min} = K \frac{S}{D^3}$$

where  $K$  is a constant that can be determined from the foregoing example where  $(p\theta)_{\min} = 400 \text{ mb.}^\circ \text{C.}$ ,  $s = 120$  feet, and  $S = 150$  pounds. Thus any shroud will be completely open when

$$p\theta > (p\theta)_{\min} = 4,600,000 \frac{S}{D^3} \text{ mb.}^\circ \text{C.}$$

where  $S$  is in pounds and  $D$  is in feet.

The chain weight in the hem is about  $0.1 S$ , but this value is not critical to the computation of volumes, and variations in the value will not substantially alter the value of  $(p\theta)_{\min}$ .

In these considerations it has been assumed that the shroud is made of an originally cylindrical tube of film of the same length as the collapsed balloon and gathered closed at one end, and is just large enough in circumference to cover the full balloon at the equator.

As an illustration, consider a  $\frac{1}{4}$ -mil Mylar balloon and shroud, each having an 80-ft. collapsed length. The weight of the shroud will be 26 pounds, the chain may weigh about 3 pounds, and the shroud will be substantially completely full when

$$p\theta > (p\theta)_{\min} = 240 \text{ mb.}^\circ \text{C.}$$

The Mylar balloon will of course also weigh 26 pounds, and have a filled-out volume of 61,500 cubic feet. With a payload of 50 pounds, this system would have a ceiling pressure altitude of 20 mb. (about 87,000 ft.)

With any shrouded system, the nighttime superheat  $\theta_n$ , required to level the system without ballast drop at a pressure altitude  $p_n$ , is

$$\theta_n = \theta_d \frac{p_d}{p_n}$$

where  $\theta_d$  is the daytime superheat at the daytime ceiling pressure altitude  $p_d$ .

While preferred embodiments have been described in some detail, they should be regarded as examples of the invention and not as restrictions or limitations thereof as changes may be made in the materials, construction and arrangement of the parts without departing from the spirit and scope of the invention.

We claim:

1. In an airborne balloon system in a geographical region of positive superheat and having a predetermined daytime ceiling altitude, a high altitude inelastic film balloon, and an air container open only at its bottom to the atmosphere and disposed outside of and supported by the balloon, the volume of air in the container being substantially in the range of  $\frac{1}{2}$  to 5 times the balloon volume

at and after the system has first reached ceiling altitude, the container weight being substantially in the range of  $\frac{1}{4}$  to  $\frac{3}{4}$  of the weight of the system, so that, after sunset, the added lift contributed by superheated air in the container will keep the system airborne throughout the night.

2. In an airborne balloon system in a geographical region of positive superheat and having a predetermined daytime ceiling altitude, an inelastic film high altitude balloon, and an inelastic film shroud open only at its bottom to the atmosphere, and carried by and surrounding the balloon, the volume of air in the shroud being substantially in the range of  $\frac{1}{2}$  to 5 times the balloon volume at and after the system has first reached ceiling altitude, the shroud weight being substantially in the range of  $\frac{1}{4}$  to  $\frac{3}{4}$  of the weight of the system, so that, after sunset, the added lift contributed by superheated air in the shroud will keep the system airborne throughout the night.

3. The structure of claim 1, characterized in that the container is of film material and envelops the balloon and is of substantially constant shape throughout the descent.

4. In an airborne balloon system in a geographical region of positive superheat and having a predetermined daytime ceiling altitude, a balloon, a load line suspended from the balloon, and an air container suspended from the line and open at its bottom only to the atmosphere, the volume of air in the container being substantially in the range of  $\frac{1}{2}$  to 5 times the balloon volume at and after the system has first reached ceiling altitude, the container weight being substantially in the range of  $\frac{1}{4}$  to  $\frac{3}{4}$  of the weight of the system, so that, after sunset, the added lift contributed by superheated air in the container will keep the system airborne throughout the night.

5. The structure of claim 1, together with a duct communicating with the top of the balloon and extending therefrom outside of the balloon to a level adjacent that of the bottom of the balloon, the duct being open at its bottom, the balloon being closed except at the top where it leads to the duct.

6. The structure of claim 1, together with a duct communicating with the top of and extending downward outside of the balloon and forming with the balloon a unit which is closed except at the bottom of the duct, the entire container being disposed below the bottom of the duct.

7. The structure of claim 1, characterized in that the container is skirt-like and has a weighted hem hanging free in the atmosphere.

8. An airborne high altitude balloon system in a geographical region of positive superheat, comprising a balloon closed at the bottom, means supported by the balloon and responsive automatically and solely to ambient meteorological phenomena for halting nighttime descent of the system from ceiling altitude while system is airborne, so that at the next sunrise the lift added to the balloon by solar radiation will enable the system to reascend, said means comprising a skirt open to the atmosphere only at the bottom of the skirt, the bottom of the skirt being unconnected to any other part of the system, the air within the skirt being in sufficient volume to provide lift compensating for sunset loss of lift of the balloon, a collapsed parachute suspended from the balloon, a payload suspended from the parachute, the skirt being located entirely below the payload, means for jettisoning the skirt, and means for thereafter jettisoning the parachute so that the parachute can open to float the payload to earth without interference from the skirt.

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