Feb. 20, 1968 A. D. STRUBLE, JR 3,369,774

BALLOON ENVELOPE STRUCTURE

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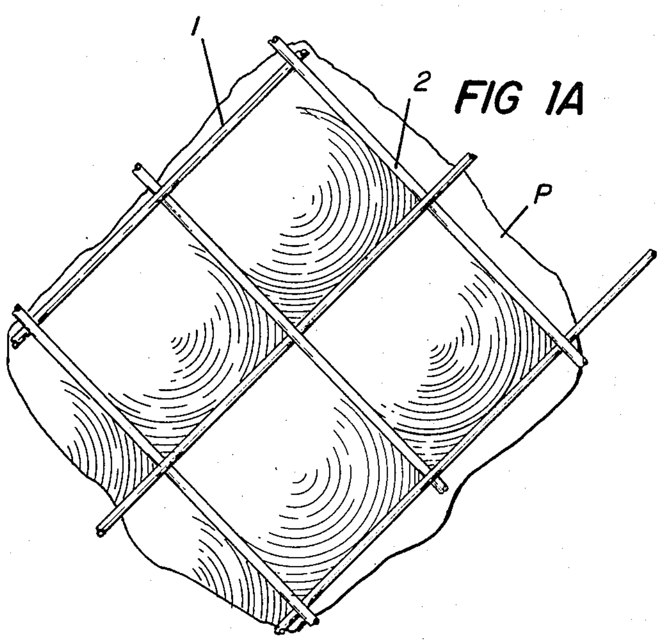
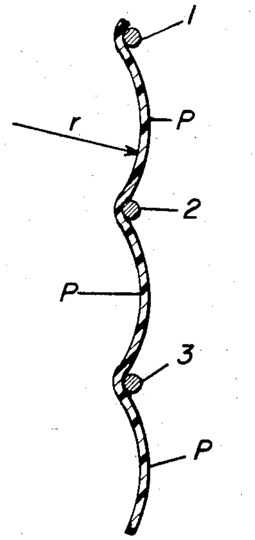


FIG 1A

FIG 2



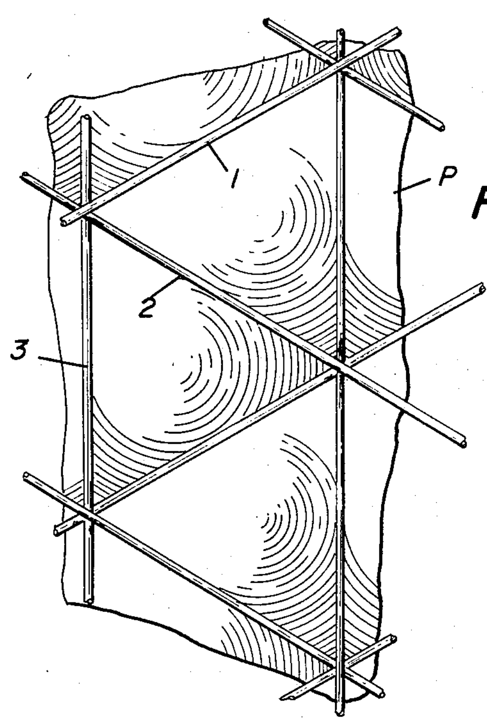


FIG 1B

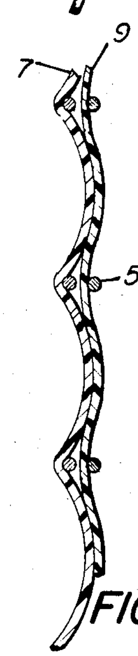


FIG 3

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BALLOON ENVELOPE STRUCTURE

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This invention relates generally to improvements in balloons and balloon systems. More specifically this invention pertains to balloons which are capable of achieving altitudes as high as 230,000 feet or more. In a specific embodiment this invention pertains to balloon vehicles constructed of a combination of very thin plastic film and relatively thin high-strength load carrying members.

As is well known, there is a continuing and increasing interest in the atmosphere above the earth. Daily weather reports and long-range meteorological forecasts are in large part possible because of the data gathered at high altitudes. Research in the upper atmosphere has also been stimulated within recent years because of the interest of the military forces of the world, who have not only been interested in the weather data which can be obtained but have also been intrigued with the reconnaissance possibilities at high altitudes. While great strides have been made in recent years in studying the characteristics of the upper atmosphere and in making flights through the atmosphere, such advances have been limited by the type of exploration equipment which is available.

It is of course well known that balloons have often been employed to obtain data in the upper atmosphere. Balloons have less frequently been used to transport human beings from one point to another. However, in order for a balloon to carry either a payload of instruments or a human being to a high altitude, the material of which the balloon is constructed must meet two requirements. It must first of all be constructed of very lightweight material (in order to maximize the buoyant effect of the gas contained therein) and secondly it must at the same time be strong enough to withstand the rigors of launching and flight through sometimes turbulent weather conditions. Since strength is usually inversely proportional to thickness and weight, those in the balloon art have heretofore been effectively limited insofar as the thickness of their balloon fabric material is concerned. This in turn has usually limited the height to which the balloon may rise.

The principal object of this invention is to provide a balloon structure and fabric which is extremely light in weight.

A still further object is to provide a balloon structure that is only 10 to 20 percent the weight of those currently employed.

These and other objects and advantages will be more apparent after reading the following description.

In its broadest concept, the balloon envelope structure of this invention is characterized by the following combination of features:

(a) a gas envelope comprising a synthetic plastic film,

(b) said plastic film having a thickness within the range of about ¼ to $\frac{1}{16}$ mil,

(c) said plastic film being essentially non-load bearing except for the gas pressure differential,

(d) said plastic film being divided into a plurality of small multi-sided panels by means of a plurality of thin, elongated strengthening grid members,

(e) the amount of plastic film within each panel being in excess so that the plastic film can billow under the influence of gas pressure and assume a comparatively small radius of curvature,

(f) said grid members functioning as the load bearing members for the balloon envelope structure.

In a narrower sense, the present invention comprises the various elements and features set forth hereinafter.

The synthetic plastic film may be of any suitable composition so long as it is capable of presenting an effective barrier against the escape of gas contained within the balloon and so long as it possesses a minimum degree of resistance against tearing or rupture by the pressure exerted by the gas within the balloon. The plastic film therefore primarily functions as a gas barrier rather than as a load carrier. Polyethylene and Mylar plastic films are preferred although Pliofilm and other materials are also suitable. It has been found that a thickness between about ⅙ and $\frac{1}{10}$ mil is preferred, and a thickness of $\frac{1}{7}$ and ⅛ mil especially preferred. Films of this thinness are feasible because of the load bearing function of the grid members.

The grid members functioning as the load bearing units for the balloon envelope structure may comprise a variety of materials. Although special high-strength glass fiber threads (manufactured by Owens-Corning) and special high carbon steel wire are preferred, other filamentary materials such as Dacron, Fortisan, etc. could conceivably be used. The high carbon steel wire preferably has a diameter of about .003 to .004 inch, depending upon the specific design, but wires having diameters within the range of about .001 to .006 inch are satisfactory. The choice of a particular wire is governed by fabrication costs, structural efficiency of the balloon envelope, size of the structure, load carrying capacity of the unit, acceleration loads that must be accommodated, etc. High carbon steel wire has exhibited an ultimate tensile strength of 587,000 p.s.i. and special glass fiber strands an ultimate strength of 191,000 to 370,000 p.s.i., but even so, these materials were comparable on a strength-to-weight ratio basis. Metallic grid members are presently preferred because of their fatigue strength, elasticity, low temperature physical characteristics, handling ease, loop strength and reliability.

Arrangements using both high carbon steel wire and high strength glass fiber have been satisfactorily employed. Glass fiber filaments that are smaller in diameter than the thickness of the plastic films can also be used, and as a consequence can be laid or imbedded in more or less uniform spacing across the plastic film. The high load carrying capacity strength members would thus be distributed in a very fine matrix over the gas barrier film. Balloon loads would thus be directly fed into the glass fiber strands with their position relative to one another held by the plastic film, rather than a number of strands being twisted into a glass fiber thread and placed at discrete intervals on the film. The loads on this glass fiber film sheet could then be taken out by terminating or pressing against high carbon steel wires that are placed at discrete intervals over the sheet to bring out the balloon loads as demanded by the particular design.

The exact shape and disposition of the load carrying grid members are not critical. Several examples of grid patterns are illustrated in FIGURES 1A and 1B, wherein the grid members are designated by the numbers **1**, **2**, and **3** and the plastic by P. Instead of these arrangements a complete shell network of very thin strands of glass fiber which completely encase the gas barrier material could be used.

I have also found that the very thin polyethylene film may, under some conditions, desirably have a double wall design (**7** and **9** in FIGURE 3) in order to provide a greater safety factor and a major reduction in the gas permeability. The films may be placed together in an intimate fashion, by using mechanical pressure, heat sealing and/or adhesives. The strength members **5**, in this case, would be flattened if possible. Flat wire .003 x .0045 appears to be a good strength member, as well as flattened multistrand glass fiber.

The area of a panel within grid members is likewise not critical and might be for example within the range of about .001 to 25 square inches, depending upon the internal pressure at that point and the ability of the gas barrier to take the pressure stresses.

As is illustrated in FIGURE 2, when the grid members **1**, **2** and **3** are arranged sufficiently close together, the plastic film strength characteristics can be reduced to a minimal value by allowing the plastic film P to be in excess so that it may "billow" and assume a relatively small radius of curvature *r* in either direction so that it in effect takes on a shape that would be the approximate section of a sphere. (The term "excess" is used in comparison to the "minimum" amount of material needed to stretch over a panel formed by two or more grid members.) Thus the basic balloon might have a radius in the order of several hundred feet, but the small panel that is allowed to billow would have a radius of curvature of perhaps only a few feet, and for the smaller sizes, perhaps several inches. Since the stresses in the film are directly proportional to the radius of curvature, allowing the film to billow will reduce the effective structural radius of curvature from several hundred feet down to, perhaps, several inches, resulting in a very major reduction in the stress loading of the film. By so doing, the limiting factors on the film thickness are no longer those of strength but of the ability to produce a very thin film with good quality control. The exact amount of "excess" or the exact degree of billowing does not appear to be critical. The excess material or billowing is a result of the productive process, or it can be a consequence of the extensibility of the film. The thin polyethylene and/or thin rubber membranes would have sufficient extensibility and would not require excess material under most conditions.

On a root-mean-square basis, a balloon prepared in the above manner has about the same strength equivalents as a 1.4 mil polyethylene film yet only 16 percent of the structural weight of a 1.4 mil polyethylene film. This is a weight improvement in the order of 600 percent.

A four-mil high carbon steel wire (manufactured by the National Standard Company of Niles, Mich.) is preferred as the grid member. Depending upon a number of conditions the wire spacing and pattern is a function of the following factors:

(1) acceleration compliance required and acceleration modes;

(2) weight distribution over the vehicle envelope;

(3) wire physical characteristics including their action as stress risers on the thin film;

(4) film thickness, quality control and internal gas pressure;

(5) fabrication costs vs. performance; and

(6) the type of mission, with particular regard to reliability.

The grid members may be fixed to the surface of the plastic film in any desired manner as for example by adhesion, thermal fusion, imbedding, etc.

When a unit is fabricated in this manner it has a total weight within the range of about .0001 to .001 pound per square foot. The plastic films are so supported by the grid members that any major overpressures due to imposed accelerations can be accommodated with ease.

The gas pressure within the balloon is normally only that associated with the static head. However, it is possible that the invention could be used with super-pressure balloons. One example of a super-pressure balloon is that sometimes used for constant altitude aerology. Another example of a super-pressure balloon is that used in high altitude rocket boost systems wherein a light plastic sphere falls from 250,000 down to 100,000 feet for aerology purposes, such balloons being required to accommodate high gas pressures. In either of the aforementioned cases the use of the teachings of this invention permits large weight savings. Structural weights in some cases can be reduced to 5 percent to 10 percent of conventional practice and super-pressure values can be provided in my balloons that cannot be accommodated at all with ordinary practice.

In summary then, the advantages of my invention are as follows:

(1) A structural design for balloon canopies which can achieve weight savings of about 84 percent.

(2) Balloon envelopes having multi-directional acceleration compliance with strength non-dependent on the gas barrier film.

(3) Reduced pressure stresses in the film barrier by use of a "billow" design.

(4) Balloon buoyancy capability involving in most cases less than 10 percent of the weight penalty associated with conventional ballasting practices.

I have, in the drawings and specification, presented a detailed disclosure of the preferred embodiment of my invention. It is to be understood that the invention is susceptible to many modifications, structural changes and various applications of use within the spirit and scope of the invention and I do not intend to limit the invention to the specific form disclosed but intend to cover all modifications, changes, alternative constructions and methods falling within the scope of the principles taught by my invention.

I claim:

1. A balloon envelope structure characterized by the following combination of features:

(a) a gas envelope comprising a synthetic plastic film,

(b) said plastic film having a thickness within the range of about ¼ to 1/16 mil,

(c) said plastic film being non-load bearing except for the gas pressure differential,

(d) said plastic film being divided into a plurality of small multi-sided panels by means of a plurality of thin, elongated strengthening grid members affixed to said plastic film,

(e) the amount of plastic film within each panel being in excess so that the plastic film can billow above and beyond its own extensibility under the influence of gas pressure and assume a comparatively small radius of curvature,

(f) said grid members functioning as the load bearing members for the balloon envelope structure.

2. A balloon envelope in accordance with claim **1** wherein said film thickness is within the range of about ⅙ to 1/10 mil.

3. A balloon envelope in accordance with claim **1** wherein said film thickness is within the range of about 1/7 1/10 mil.

4. A balloon envelope in accordance with claim **1** wherein said plastic film is polyethylene terephthalate.

5. A balloon envelope in accordance with claim **1** wherein said plastic film is polyethylene.

6. A balloon envelope in accordance with claim **1** wherein said elongated strengthening grid members comprise high carbon steel wire.

7. A balloon envelope in accordance with claim 1 wherein said grid members comprise high strength glass fiber.

References Cited

UNITED STATES PATENTS

2,767,940	10/1956	Melton	244—31
1,023,759	4/1912	Rectenwald	244—31
1,332,107	2/1920	Coates	244—31
2,767,941	10/1956	Gegner et al.	244—31
2,960,282	11/1960	Winzen	244—31

FOREIGN PATENTS

Bilhorn, "Balloons for Scientific Research," Astronautics and Aeronautics, American Institute of Aeronautics and Astronautics, New York, vol. 3, No. 12 (December 1965), TL 787.A83 pp. 42–46 relied on.

1965 Diary, General Electric Co., p. 34 relied on.

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