

March 12, 1946.

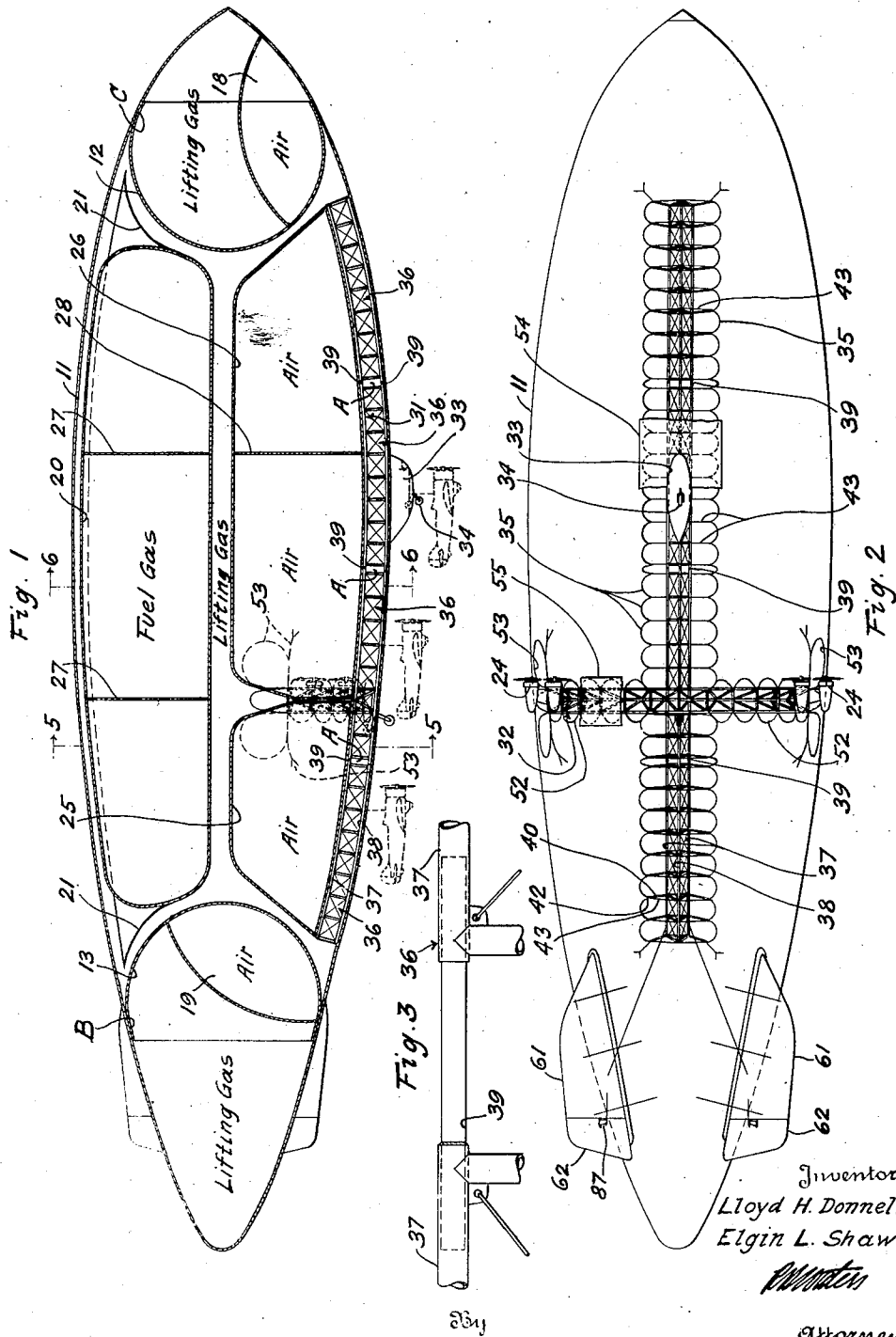
L. H. DONNELL ET AL

2,396,494

AIRSHIP

Filed July 16, 1941

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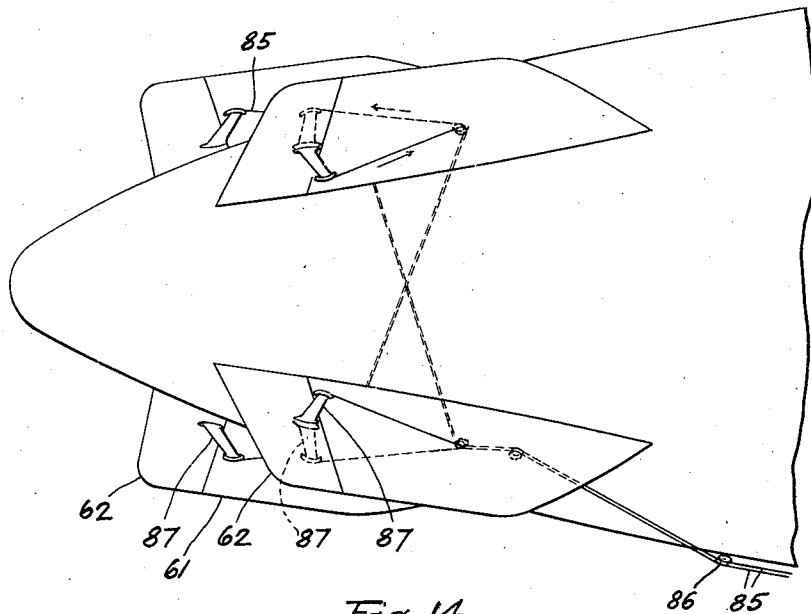


Fig. 14

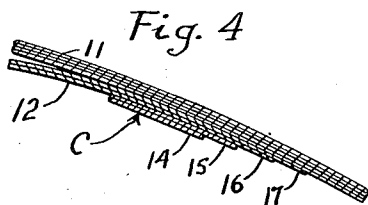


Fig. 4

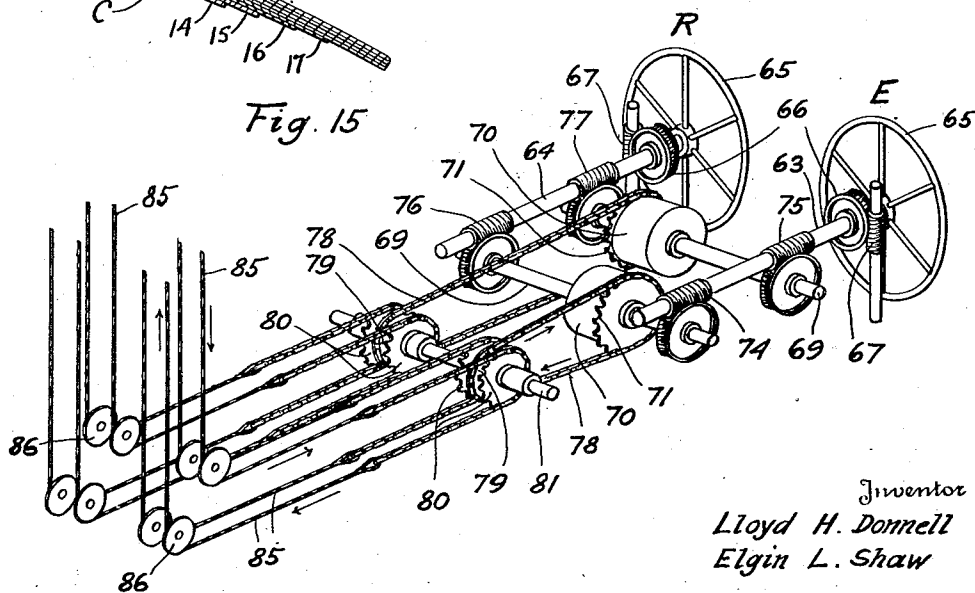


Fig. 15

Inventor
Lloyd H. Donnell
Elgin L. Shaw

By

[Signature]

Attorney

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Fig. 6

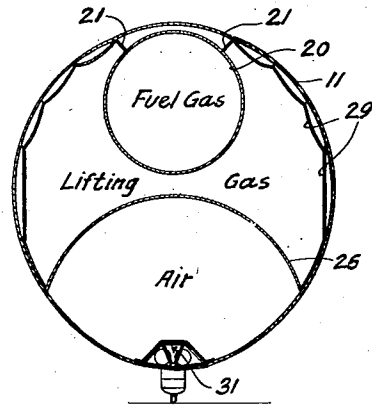
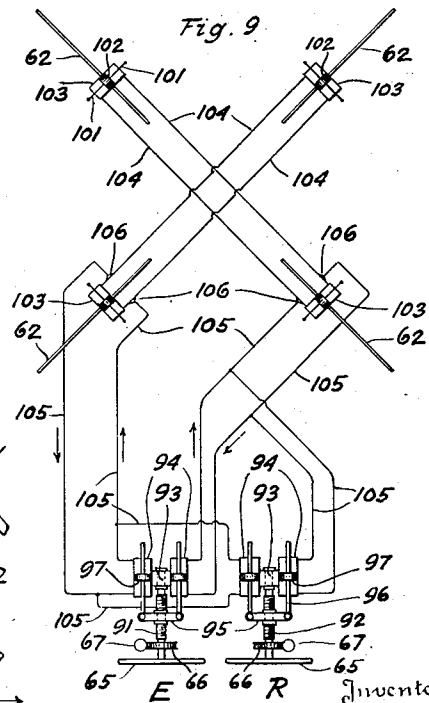


Fig. 9



66 R Inventor
Lloyd H. Donnell
Elgin L. Shaw

Attorney

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L. H. DONNELL ET AL.

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Fig. 16

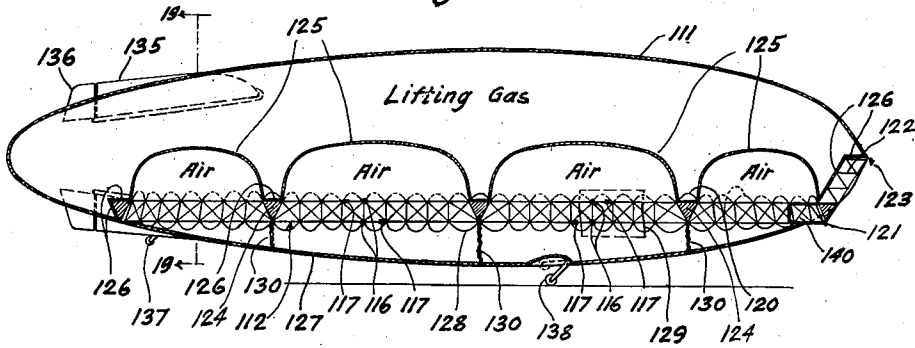


Fig. 17

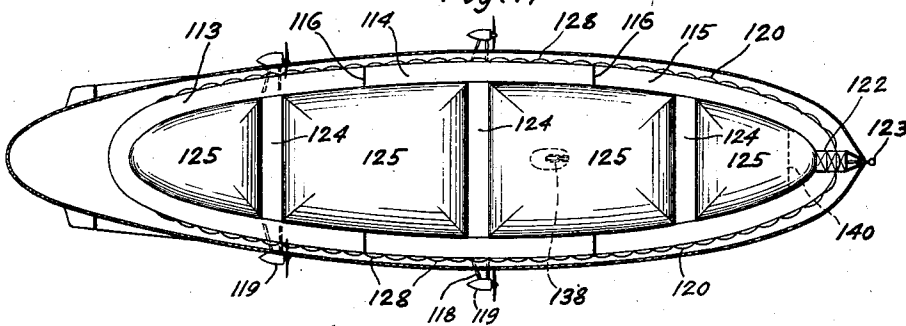


Fig. 18

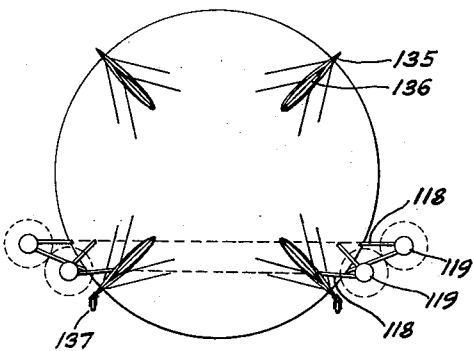


Fig. 19

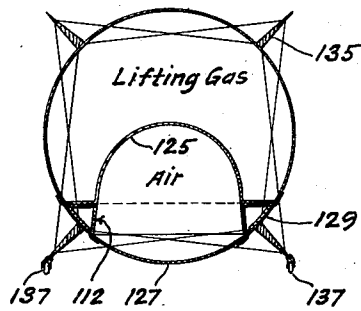
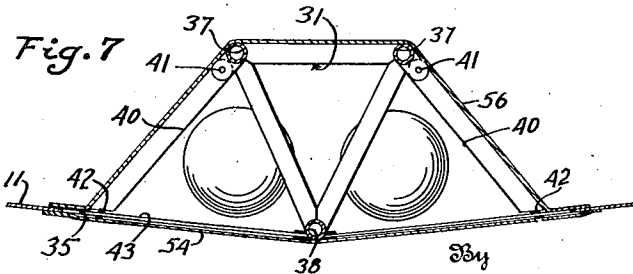


Fig. 7



Inventors
Lloyd H. Donnell
Elgin L. Shaw

Winters

attorney

UNITED STATES PATENT OFFICE

2,396,494

AIRSHIP

Lloyd H. Donnell, Chicago, Ill., and Elgin L. Shaw, Akron, Ohio, assignors to Wingfoot Corporation, Wilmington, Del., a corporation of Delaware

Application July 16, 1941, Serial No. 402,586

11 Claims. (Cl. 244—30)

The present invention relates to the construction of non-rigid airships which incorporate rigid structures for carrying the various service loads.

One object of this invention is to improve and to simplify the construction of this type of airship by entirely avoiding the rather complicated internal cable suspension of conventional design.

Another object of this invention is to stiffen the bow, as well as the stern portion of the airship without employment of rigid structural means.

A further object of this invention is to make the rigid structure carrying the loads sufficiently yieldable, so it can adjust itself to the changeable shape of the gas bag and at the same time is capable of taking shear forces.

Another object of this invention is to arrange the empennage of the airship in such a way that its lowest point is far enough away from the ground to prevent striking it at a take-off or landing.

For a better understanding of this invention reference will now be made to the accompanying drawings of which:

Fig. 1 is a vertical longitudinal section taken through the center of the airship.

Fig. 2 is a bottom view of Fig. 1, with most of the outer cover along the gangways omitted.

Fig. 3 represents in enlarged scale, a flexible joint of the longitudinal corridor at points A.

Fig. 4, also in enlarged scale, is a longitudinal section through the outer cover at the points B and C of Fig. 1.

Fig. 5, left side, is a rear view of the airship, and the right side is a cross-section taken on the line 5—5 in Fig. 1.

Fig. 6 is a cross-section taken on the line 6—6 in Fig. 1.

Fig. 7 is a cross-section in enlarged scale of the corridor as shown in Fig. 6.

Fig. 8 is a diagrammatic view of the rudder and elevator control, operated mechanically.

Fig. 9 is a modification of this control, operated hydraulically.

Fig. 10 is a diagram showing the position of the control surfaces when operated as elevators only, the arrow indicating the direction in which the stern moves.

Fig. 11 is a diagram showing the position of the control surfaces when operated as rudders only, the arrow indicating the direction in which the stern moves.

Figs. 12 and 13 are diagrams showing the position of the control surfaces as a result of operating the rudder and elevator worm shafts at the same speed, the arrows indicating the direction in which the stern moves.

Fig. 14 is a perspective view of the empennage of the airship showing more clearly the connec-

tion of the control lines to the control surfaces.

Fig. 15 is a perspective view in larger scale, of the rudder and elevator surface control mechanism.

Fig. 16 is a vertical longitudinal section of a modification of the airship construction shown in Fig. 1.

Fig. 17 is a horizontal section taken on the center line of Fig. 16.

Fig. 18 is a rear end view of Fig. 16; and

Fig. 19 is a cross-section taken on the line 19—19 of Fig. 16.

Referring to the drawings, numeral 11 represents the outer gas bag or envelope of the airship which is provided with spherical bulkheads 12 and 13 located at the bow and at the stern, respectively. Each one of these bulkheads forms, together with the front and rear portion respectively of the envelope 11, a separate gas container which is kept at about twice the pressure as that in the main gas space to make the bow and stern sufficiently resistant against aerodynamic forces acting upon them, thereby dispensing with the conventional air resistance creating battens on the outside of the envelope. In order to secure a smooth outer shape of the envelope and to avoid bulging of same where the bulkheads 12 and 13 are connected to it, that is, where the difference in pressure on the envelope occurs, inner reinforcing strips 14 and 15, made of different widths, are staggered like the edges 16 and 17 of the bulkheads, thus gradually decreasing again the wall of the envelope towards the ends to its normal thickness. Airbags 18 and 19, respectively, control the pressure in the front and rear gas cells. Within the envelope 11 a fuel gas container 20, suspended by aprons 21 from the top of the envelope, is provided with an inflation line 22 (see Fig. 5) suspended by supports 23, and feeds the power units 24. The space which becomes free while the fuel gas is being consumed is taken up by air forced into the bags 25 and 26 which keep the main envelope always in taut condition. Bulkheads 27 divide the fuel gas container into several compartments to reduce surging of the gas. For the same purpose also the larger airbag 26 is provided with a bulkhead 28. To protect the lifting gas against superheat, loose curtains 29 (Fig. 5), made of light gas-proof fabric, are suspended just a short distance away from the airship envelope. These curtains also are to serve the purpose to automatically seal the envelope against loss of gas in case of injury.

The structural portion of the airship consists of a longitudinal gangway framework 31 of triangular cross-sectional shape extending inside along the bottom in the center of the airship and of a transverse triangular gangway 32.

The longitudinal gangway carries practically

all the service loads of the airship distributed over its length, like liquid fuel, oil, ballast, etc., and the control car 33 is attached underneath. This car is equipped with a retractable landing wheel 34. If desired airplanes may also be suspended from this gangway as indicated in dotted lines in Fig. 1.

One of the new features of this airship construction is that the load carrying longitudinal gangway is entirely supported by catenaries 35 extending circumferentially from the gas envelope without requiring any interior suspension members. To combine the advantages of a non-rigid airship with that of a rigid gangway structure this rigid structure is made in four sections 36 telescoping into each other as in Fig. 3. The chord members 37 and 38 of these sections are provided at one end with welded-in stubs 39 (Fig. 3) which are made with sufficient clearance as to be easily slidable in the chord members of an adjacent gangway section. Thus, the slidable joints are made sufficiently transversally flexible to permit the gangway to follow the changing shape of the airship envelope during flight without creating undue stresses in the structure which, therefore, can be made relatively light in weight. This joint construction, though not capable of resisting bending, tension and compression forces, can transmit shear forces. Laterally the longitudinal gangway is braced by struts 40 (see Fig. 7) which are joined pivotally at their inner ends at 41 to the upper chord member 37 of the gangway, and their outer ends 42 are connected by braces 43 made of wire or cable to the lower chord member 38. These braces 43 also connect to the catenaries 35 of the envelope.

The construction of the transverse gangway 32 to which are attached outriggers 46 carrying the power units 24 is similar to that of the longitudinal gangway, however, with the difference that its outer chord members 47 are hinged to the longitudinal gangway as at 48, and only the inner chord member 49 is made slidable at 50 similar to the construction shown in Fig. 3, giving the transverse gangway the necessary flexibility. A cable 51 connects the top ends of the transverse gangway to limit their spreading apart. The transverse gangway is supported by the envelope by means of catenaries 52 (see Fig. 2). Catenaries 53 near the equator in the side of and tangentially to the envelope take up the propeller thrust and most of the engine weight. The openings between the gangway catenaries are closed by covers 54 and 55 respectively, which are laced and sealed to the envelope. On the inside, the bottom gangway structure is enclosed by a fabric covering 56 (see Fig. 7), and fireproof coverings 57 (see Fig. 5) enclose portions of the side gangways to provide for engine control rooms 58.

Another new feature of this airship construction is the diagonal arrangement of the empennage consisting of fins 61 and of control surfaces 62. This arrangement has the advantage that injuries to the control surfaces due to take-offs and landings are less likely to occur than is the case with the conventional empennage arrangement. Thus, a steeper take-off is possible which is necessary when starting with overloads. With this new arrangement all four control surfaces are operated simultaneously, either from the control car at 33 or from the rear end of the gangway 36 from one handwheel, either as elevators or as rudders, respectively. Therefore, in each case a larger control surface area is available. However, due to the diagonal arrangement of

the surfaces only a component of the force acting on them is effective, either vertically or horizontally. Whereas, when both handwheels are operated, say at the same speed, always one pair of surfaces lying in the same plane is counteracted in its movements by opposite operating forces and thus remains in zero position; but the other pair of surfaces, because both wheels tend to rotate them in the same direction, are deflected at an angle twice as large as when all four surfaces are deflected simultaneously.

Fig. 8 illustrates an example of a control mechanism for the elevators and rudders of which 63 and 64 are worm shafts operated either by handwheels 65 or by worm gears 66 in engagement with worms 67 driven by servo motors (not shown). The worm shafts 63 and 64 operate upon differential shafts 68 and 69, respectively, on each of which is mounted a differential gear 70 provided with a sprocket 71. The worms 74 and 75 on the elevator worm shaft at E are both right hand, whereas the worms 76 and 77 on the rudder worm shaft at R are right hand and left hand, respectively. The sprockets 71 of both differential gears work by chains 78 upon sprockets 79, each of which being fixedly connected to a pair of sprockets 80 and revolving together loosely about a fixed transmission shaft 81. Control lines 85 operate over the sprockets 80 and sheaves 86 to actuate the levers 87 to thus control the surfaces 62. Both pairs of control surfaces can be operated together by either the worm shaft 63 only as elevators or by the worm shaft 64 only as rudders. When operating both worm shafts at the same time the movement of one pair of surfaces, due to the differential gears will be accelerated in the same direction and the angle of deflection increased proportionately, and that of the other pair will be accordingly retarded or completely nullified, depending on the speed and direction of rotation of the worm shafts.

A modification of the elevator and rudder control, described above, is illustrated by Fig. 9, in which the mechanical control is substituted by a hydraulic type.

The operating spindles 91 at E and 92 at R, one operating the control surfaces as elevators and the other one operating these same surfaces as rudders, are made to turn either by hand or by servo motor as described for mechanical control. Each spindle turning in a bearing 93, located between and connecting a pair of hydraulic cylinders 94, engages a crosshead 95, both ends of which are linked to piston rods 96 for moving the pistons 97 in the cylinders 94. On the other hand the levers or segments 87 of each control surface are connected to opposite ends of a piston rod 101 of the piston 102 moving in the transmission cylinder 103. Corresponding ends of each pair of these cylinders pertaining to a pair of control surfaces which swing about the same axis are connected by a hose or pipe line 104. In order to manipulate from one operating spindle, for instance, the elevator spindle E, all control surfaces at once, the ends of one operating cylinder are connected to the lines 104 of one pair of transmission cylinders, and the ends of the other operating cylinders are connected to the lines 104 of the other pair of transmission cylinders by lines 105 in such a way that when the operating spindle is turned the transmission liquid, by means of the pistons of the transmission cylinder, causes all control surfaces to deflect in one direction, that is, either up or down, depend-

ing on which way the spindle is turned (see Fig. 10).

The operating cylinders at R are also connected to the lines 104, but in such a way that when their pistons move one pair of control surfaces deflects upwardly and the other pair downwardly and in opposite directions, respectively, depending on the direction in which the spindle turns. That is, because in this case the connections at 104 of the lines 105 coming from the cylinder 94 at the right side are reversed as compared with the connections of the lines 105 coming from the left cylinder 94, and therefore the control surfaces act as rudders (see Fig. 11). The arrow indicates the direction in which the stern of the airship will move.

When operating both the elevator control E and the rudder control R, at the same speed, two operating pistons, one from E and the other one from R, work upon one pair of control surfaces in the same direction causing a 100% of the possible deflection (see Figs. 12 and 13), whereas the two other operating cylinders are cut short. In other words, the liquid in the front chamber of one of these operating cylinders is pushed into the rear chamber of the other operating cylinder and vice versa. Therefore, no forces are acting upon the other pair of control surfaces and it remains in its position. The deflected pair of control surfaces then acts simultaneously as an elevator and as a rudder and the ship will move in vertical and in transverse direction. Of course, when turning both spindles simultaneously but at a different rate of speed a lesser percentage of deflection than 100% of the one pair of surfaces, and some deflection of the other pair of surfaces, will be the result. It is seen, that this hydraulically operated control acts exactly like a mechanically operated control.

A simplified modification of this invention adaptable particularly for airships of smaller size is illustrated by the Figures 16 to 19, in which the numeral 111 represents the flexible bag containing the lifting gas. A load carrying gangway 112 of triangular cross-section is made up of sections 113, 114 and 115, which are connected by hinges 116 and by transversally flexible sliding joints 117 similar to that shown in Fig. 3, to permit the gangway to yield vertically sufficiently to adapt itself to eventual deformations of the gas bag and to prevent undue stresses in the rigid structure. The gangway which is oblong in shape carries all loads including the outriggers 118 which support the power plants 119, and is suspended entirely by the catenaries 120 extending from the edge along the bottom of the gas bag. The position of the gangway is located considerably below and substantially parallel to the equator of the airship and its outer contour corresponds substantially to that of the gas bag, except at the rear end where it emerges into the gas bag and at the front where it somewhat protrudes the gas bag to provide for a suitable mooring point 121. In front at the center of the gangway a girder 122 extends upwardly and forwardly as far as the center of the bow where a mooring cone 123 is attached. Horizontally, the gangway is braced by transverse keel girders 124 which also serve as gangways from one side of the airship to the other. At the outside of the lateral gangways, where the transverse braces connect, the four engine outriggers 118 are attached. Along the inside upper edge of the gangway girders and along the upper edges of the transverse girders air ballonets 125 are attached,

and sealing strips 126 cover these girders to make the gas bag gas-tight at the bottom. The bottom cover 127 of the airship which closes the airbags against the outside is fastened by means of catenaries 128 to the bottom edge of the gangway 112. The open space between the catenaries of the gas bag and those of the airbags is sealed by cover strips 129. Diaphragms 130 divide the air space into four compartments to prevent too much surging of the air and to secure better maneuverability of the airship.

The four fins 135 and control surfaces 136 are arranged in the same way as described for the earlier presented construction. A landing wheel 137 is attached to each one of the bottom fins for their protection, and a retractable landing wheel 138 is built into and underneath the bottom cover which acts as a landing cushion.

The control room 140 from which the airship is being operated is located at the front of and between the lateral gangway girders.

Having described this invention in detail, it is to be understood that its construction is not limited to the examples presented and illustrated, but that many changes and combinations may be made without departing from the spirit and scope of this invention as defined by the attached claims.

Having thus fully described our invention, what we claim and desire to secure by Letters Patent of the United States is:

1. A non-rigid airship comprising a flexible lifting gas envelope, a rigid gangway structure located inside of said envelope and conforming in its outer shape substantially to the contour of said envelope, said envelope having an opening defined by the edges of said gangway structure whereby said structure can be inserted into said envelope catenaries on said envelope bounding the edges of said opening and connected to said gangway and serving as the sole suspension means for said gangway structure, and a cover over the opening and gangway structure to complete the normal streamlined contour of the envelope.

2. A non-rigid airship comprising a flexible lifting gas envelope, a rigid gangway structure conforming in its outer shape substantially to the contour of said envelope, said structure being built in sections, longitudinally telescoping joints connecting adjacent gangway sections, said joints being capable of resisting shear forces and permitting limited lateral movement whereby the gangway sections can adapt themselves to follow the yielding shape of said envelope to avoid undue bending stresses in said gangway, said envelope having an opening along the edges of said gangway structure for inserting said structure into said envelope, and catenaries bounding the edges of said opening attached to said envelope and gangway to serve as the sole supporting means for said gangway structure.

3. A non-rigid airship comprising a flexible lifting gas envelope, a longitudinal and a transverse gangway located within said envelope with their shapes conforming substantially to the outer contour thereof, said gangway being built in sections, longitudinally telescoping joints connecting adjacent gangway sections, said joints being capable of resisting shear forces and permitting limited lateral movement whereby the gangway sections can adapt themselves to follow the yielding shape of said envelope to avoid undue bending stresses in said gangway, said envelope having an opening along the edges of said gangway for inserting said structure into said envelope

lopes, catenaries on said envelope bounding the edges of said opening and connected to said gangway to serve as a supporting means for said gangway, and a cover closing said opening.

4. A non-rigid airship comprising a flexible lifting gas envelope, a longitudinal gangway located within and conforming in its shape to the contour of said envelope and being of triangular cross-section the apex of which points downwardly, transverse struts with their one end pivotally connected to upper chord members of said gangway and transverse flexible tension members connecting the apex chord member of said longitudinal gangway with the lower ends of said transverse struts, said envelope having an opening along said gangway, and catenaries on said envelope along said opening connected to the joints of said transverse struts and tension members and serving as a supporting means for said longitudinal gangway.

5. A non-rigid airship comprising a flexible lifting gas envelope, a longitudinal flexible gangway structure located within and conforming in its shape to the curvature of said envelope, said structure consisting of rigid sections connected together by telescopic joints capable of resisting shear forces and being sufficiently yieldable to permit said gangway structure to adapt itself to the changeable shape of said envelope, said envelope having an opening along said gangway structure and catenaries on said envelope along said opening connected to said gangway structure to form a supporting means therefor.

6. A non-rigid airship comprising a flexible envelope consisting of an upper portion extending below the equator of the envelope and of a lower portion spaced therefrom, catenaries on said envelope along the edges of said upper and lower portions, a load carrying gangway structure between said upper and said lower portion conforming in its shape substantially to the outer contour of said envelope, said gangway structure being connected to and suspended from the envelope solely by the catenaries of said upper envelope portion, said lower envelope portion being connected to and suspended by its catenaries from said gangway structure, a cover connecting said upper and lower envelope portions, and at least one gas-tight diaphragm attached to said gangway structure separating the upper gas space from the lower air space in said airship envelope.

7. A non-rigid airship comprising a flexible envelope consisting of an upper portion extending below the equator of the envelope and of a lower portion spaced therefrom, catenaries on said envelope along the edges of said upper and lower portions, a load carrying gangway structure between said upper and said lower portion conforming in its shape substantially to the outer contour of said envelope, said gangway structure being connected to and suspended from the envelope solely by the catenaries of said upper envelope portion, said lower envelope portion being connected to and suspended by its catenaries from said gangway structure, a cover connecting said upper and lower envelope portions, at least one gas-tight diaphragm attached to said gangway structure separating the upper gas space from the lower air space in said airship envelope, and vertical diaphragms dividing the air space into several compartments.

8. A non-rigid airship comprising a flexible envelope consisting of an upper portion extending below the equator of the envelope and of a

lower portion spaced therefrom, catenaries on said envelope along the edges of said upper and lower portions, a load carrying gangway structure between said upper and lower portions conforming in its shape substantially to the outer contour of said envelope, transverse girders bracing said gangway structure, said gangway structure being connected to and suspended solely by the catenaries of said upper envelope portion, said lower envelope portion being suspended by catenaries from said gangway structure, a cover gas-tightly connecting said upper and lower envelope portions, gas-tight diaphragms attached to said gangway structure and separating the gas space from the air space below and vertical diaphragms at said transverse girders dividing the air space into several compartments.

9. A non-rigid airship comprising a flexible envelope consisting of an upper portion extending below the equator of the envelope and of a lower portion spaced therefrom, catenaries on said envelope along the edges of said upper and lower portions, a load carrying gangway structure between said upper and lower portions conforming in its shape substantially to the outer contour of said envelope, transverse girders bracing said gangway structure, said gangway structure being connected to and suspended solely by the catenaries of said upper envelope portion, said lower envelope portion being suspended by catenaries from said gangway structure, a cover gas-tightly connecting said upper and lower envelope portions, transverse girders bracing the side portions of said gangway structure, vertically yieldable but shear resisting joints dividing said gangway structure in sections longitudinally to make it laterally flexible so that it may flex to follow eventual longitudinal deformations of the envelope without being subjected to undue bending stresses, flexible diaphragms attached to said gangway structure and forming together with said upper envelope portion a sealed lifting gas container and together with said lower envelope portion an air container, and flexible transverse diaphragms fastened to said transverse girders subdividing said air container into a plurality of compartments.

10. A non-rigid airship comprising an envelope, a load carrying gangway structure longitudinally of and conforming in its shape substantially to the contour of said envelope, catenaries along said envelope tangentially suspending said gangway structure, and yieldable shear-resisting joints arranged longitudinally along said gangway structure dividing it in sections and thus being adapted to follow eventual longitudinal deformations of said envelope without being subjected to undue bending stresses.

11. A non-rigid airship comprising a flexible lifting-gas envelope, a rigid longitudinal structure, a rigid transverse structure comprising sections built out, substantially at right angles, on both sides of the longitudinal structure, both of said structures being located within and having their outer surfaces conforming substantially to the contour of said envelope, means pivotally connecting the transverse sections to the longitudinal structure for vertical pivotal movement of the transverse sections about the longitudinal structure, and a tension member tying together the outer ends of said transverse sections.

LLOYD H. DONNELL.
ELGIN L. SHAW.