June 10, 1930. W. B. KLEMPERER 1,763,590

STABILIZING APPARATUS FOR AIRSHIPS

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Fig. 1.

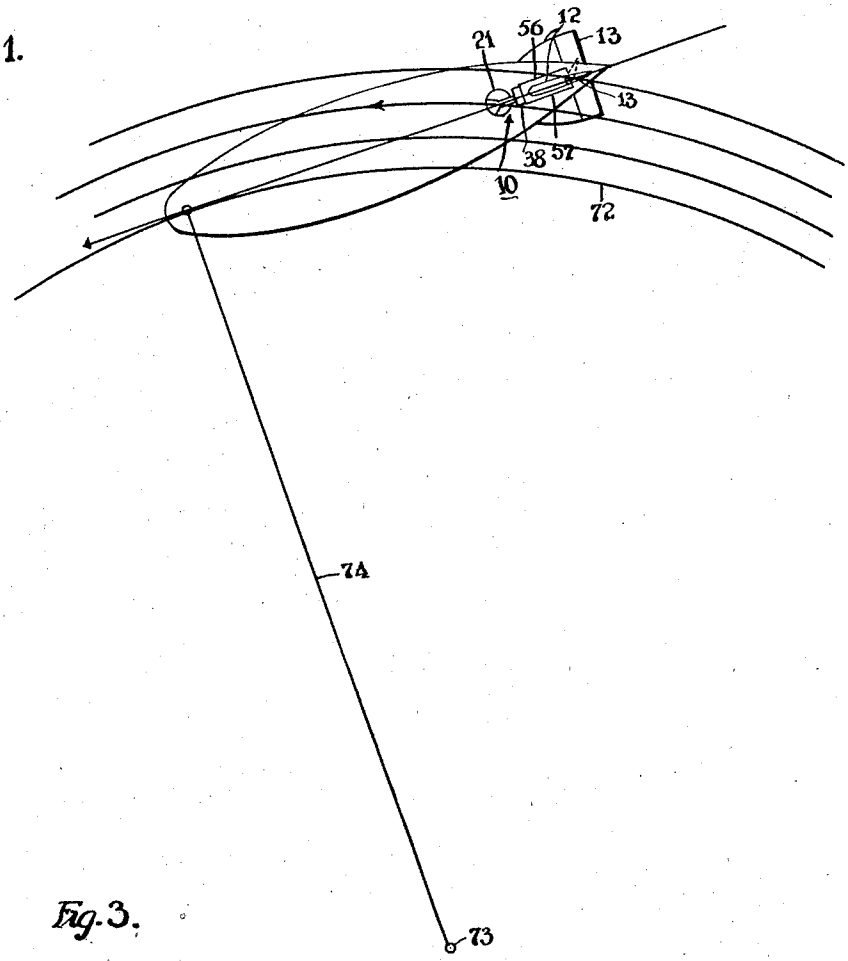


Fig. 3.

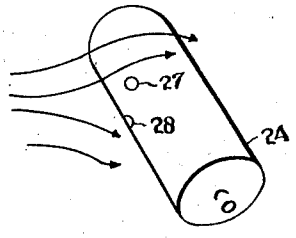
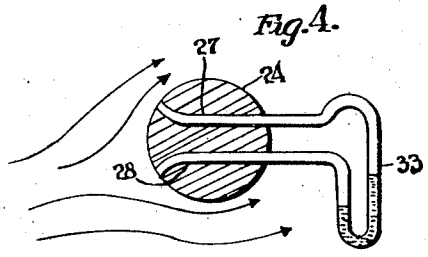


Fig. 4.



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STABILIZING APPARATUS FOR AIRSHIPS

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Fig. 2.

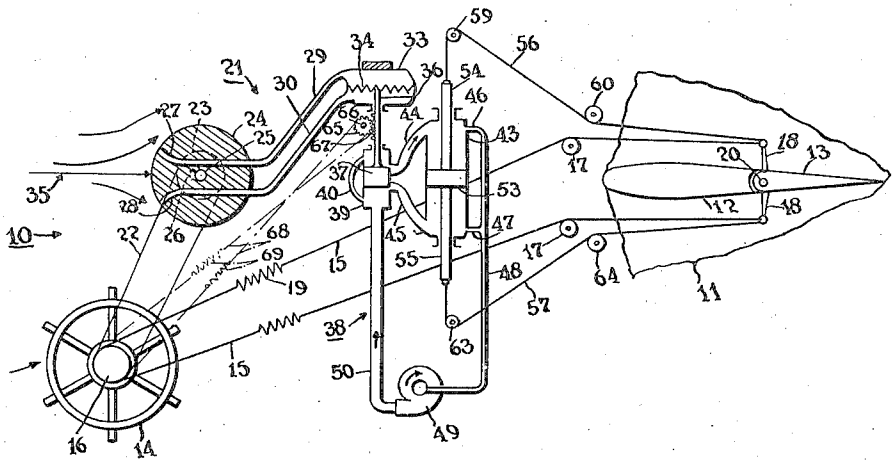
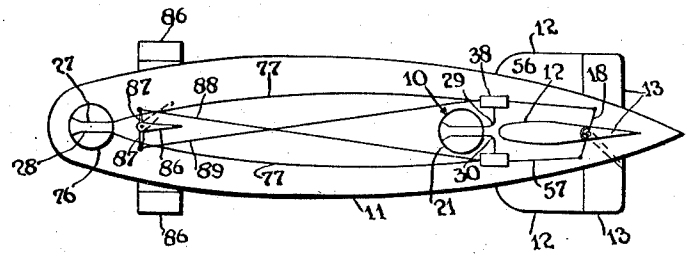


Fig. 5.



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STABILIZING APPARATUS FOR AIRSHIPS

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Fig. 6.

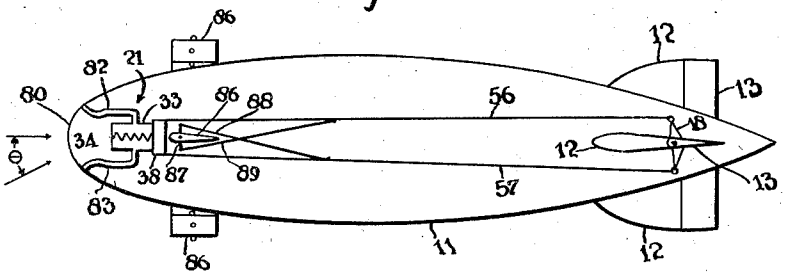


Fig. 7.

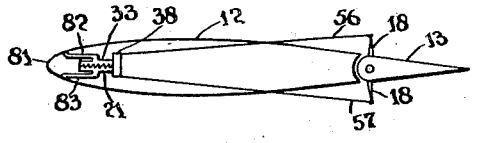
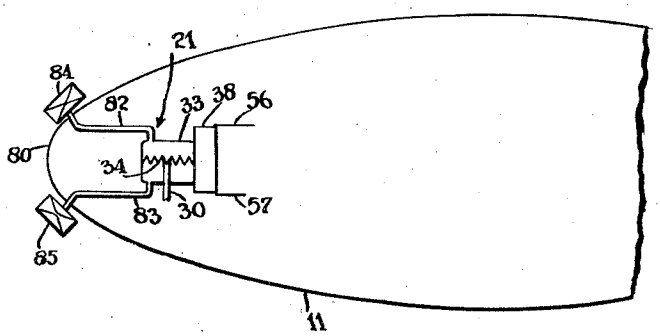


Fig. 8.



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UNITED STATES PATENT OFFICE

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STABILIZING APPARATUS FOR AIRSHIPS

Application filed April 22, 1927. Serial No. 185,837.

My invention relates to steering apparatus for aircraft and it has particular relation to apparatus for stabilizing dirigible airships of the so-called lighter-than air type.

One object of my invention is to provide an apparatus which is operable in conjunction with the rudders or elevators of an airship and tends to maintain the airship in flight in a substantially straight course regardless of exterior forces acting thereon.

Another object of my invention is to provide an apparatus which controls the direction of flight of an airship by automatically responding to changes in air currents encountered under various conditions of operation.

Another object of my invention is to provide an apparatus adapted to be installed at various locations upon an airship, such apparatus being automatically operable in conjunction with the rudders to compensate for external air forces acting upon the airship which tend to change its course.

My invention is primarily applicable to that type of dirigible airship in which the lifting power is provided by a buoyant gas contained in an elongate hull, the longitudinal axis thereof being coincident with the direction of propulsion of the ship. As a rule, it was heretofore required that the helmsman constantly devote his attention to the manipulation of the rudder steering gear in order properly to maintain the ship directionally stable or to maintain it in a straight course. Changing air currents or gusts frequently strike an airship and naturally render it much more unstable and difficult to steer than it would be in calm air. Such instability can be obviated, to a great extent, by providing fins of extremely large area at the stern of the ship. However, the advantage of employing extremely large fins can be realized only at the expense of proper maneuverability, strength, housing facilities, etc., of the structure.

An apparatus embodying the principles of my invention obviates the disadvantages referred to and the helmsman is relieved of the necessity of constantly balancing the airship to maintain it on its course. The apparatus comprises a device including one or more yawmeters connected to a servo-motor or other suitable type of actuating mechanism which, when energized under the influence of the yawmeters, serve to manipulate the rudders. Manually controlled steering gear is included as a part of the apparatus and is adapted to be operated to energize a servo-motor independently of the yawmeters. This construction is applicable for actuating rudders or elevators situated at either or both ends of the airship hull. By the term yawmeter is meant a device which is sensitive and responsive to the direction of relative air flow at the region of its location.

For a better understanding of the invention, reference may now be had to the accompanying drawings forming a part of this specification, of which:

Fig. 1 is an elevational view illustrating diagrammatically an airship embodying my invention and certain characteristics of a portion thereof;

Fig. 2 is a diagrammatical view on a larger scale, partially in elevation and partially in cross-section, of the several elements constituting an apparatus embodying one form of my invention;

Fig. 3 is a perspective view showing in detail the construction of one of the elements of a yawmeter which is embodied in the invention;

Fig. 4 is a cross-sectional view of the element shown by Fig. 3 and together with a tube containing liquid adapted to serve as a manometer;

Fig. 5 is an elevational view of an airship illustrating diagrammatically another form which my invention may assume;

Fig. 6 is an elevational view similar to that shown by Fig. 5 illustrating another form in which the advantage of the invention may be realized;

Fig. 7 is a diagrammatical view of a fin of an airship illustrating the application thereto of a device embodying my invention; and,

Fig. 8 is a fragmentary diagrammatical view including an illustration of still an-

other form which the yawmeter may assume.

In practicing my invention I provide a stabilizing apparatus generally indicated by the numeral 10, which is mounted upon or within an airship hull 11. The hull rigidly supports vertically and horizontally disposed fins 12 having rudders 13 secured thereto. It is to be understood that the term "rudder" employed in this application is intended to embrace both vertical and horizontal steering aerofoils, the latter being known specifically as elevators.

The apparatus 10 includes and is combined with a steering wheel 14 mounted in any suitable manner upon the airship hull and is provided with cables 15 extending from a central pulley portion 16 thereof, over idler pulleys 17, and thence to oppositely disposed rigid projections or struts 18 of the rudder 13. Suitable resilient elements 19 are provided in the cables 15 to compensate for sudden movements of the steering apparatus. A pivotable connection 20 is provided for securing the forward end of the rudder 13 to the hull 11 and to the fin 12.

A second cable 22 is also trained about the pulley portion 16 of the steering wheel and about a pulley 23 rigidly secured to a yawmeter 21 that includes a cylindrical yaw-sensitive element 24 rotatably mounted, as indicated at 25, upon a suitable portion of the airship hull; for example, upon the nose portion thereof or upon the leading edge of a fin or gondola. A latch 26, or other suitable device, is adapted to be employed to secure the yaw-sensitive element 24 against rotation under normal conditions of operation.

A pair of symmetrically arranged ducts or air passages 27 and 28 extend through the element 24 and are provided with flexible conduits 29 and 30 leading to a manometer 33. The manometer may be provided with a diaphragm 34 or it may be provided with mercury, as shown by Fig. 4. It will be observed that the yaw-sensitive element 24 and the manometer 33 constitute the principal parts of the yawmeter 21. The ducts 27 and 28 are open toward the forward end of the airship and are distributed in two windward quadrants of the cylindrical element 24. The wind pressures at the ends of these ducts are equal when the air flow is not yawed away from the plane of symmetry between the exposed ends of the ducts, such plane being indicated at 35. The cylindrical element 24 is adapted to be disposed in a vertical position or in a horizontal position, or two such elements may be provided, one of which may be disposed vertically and the other of which may be disposed horizontally.

When the air flow against the yaw-sensitive element 24 is at an angle to the plane of symmetry, the resulting difference in air pressure at the exposed ends of the ducts 27 and 28 is measured by the manometer 33. The diaphragm 34 of the manometer, which is sensitive to this difference in air pressure, is connected to a rod 36 having a piston 37 secured thereto that constitutes an element of a servo-motor indicated generally by the numeral 38. A cylinder 39, within which the piston 37 is disposed, is provided with a by-pass pipe 40 having its connections to the cylinder above and below the piston. The cylinder 39 communicates with a second cylinder 43 by means of conduits 44 and 45. The cylinder 43 is also provided with conduits 46 and 47 connected adjacent the opposite ends thereof and communicating with a common conduit 48, the latter being connected to a power unit 49 of the servo-motor. An additional conduit connection 50 leads from the power unit 49 to the cylinder 39. A piston 53, having oppositely disposed rods 54 and 55, is positioned centrally within the cylinder 43 and is provided with cables 56 and 57 secured thereto and trained over idler pulleys 59—60 and 63—64 respectively. Both of these cables are connected to the struts 18 of the rudder in substantially the same manner as the ends of the cable 15 are connected thereto.

In its normal position, the piston 37 partially closes the conduits 44 and 45, but upon movement of the piston in either direction resulting from operation of the diaphragm 34 by the yawmeter, the servo-motor is energized and the rudder is actuated, the direction of movement depending upon the direction of pressure against the diaphragm of the manometer.

It is to be understood that the servo-motor 38 exemplifies only one form of power supplying device for actuating the rudder 13 and that any suitable mechanical or electrical motor may be employed for this purpose and with equal efficiency.

Mechanical actuation of the piston 37 may be effected by operating a pinion 65 rotatably mounted upon a suitable element 66 of the airship and which engages a rack 67 formed on the shank of the rod 36. A cable 68, having resilient elements 69 therein, is trained about a portion of the pinion 65 and about the pulley portion 16 of the steering wheel 14, thereby providing an operative connection by which the helmsman may energize the servo-motor at will.

The relative yaw which would occur between the airship and the air flow by any virtual atmospheric disturbance controls the operation of the stabilizer and thereby the operation of the rudder 13. Thus the stabilizer always tends to arrest turning movement of the airship which may have been caused by an external atmospheric disturbance such as a gust, and the airship would

be directed into a straight path or in other words, the path of the airship would be straightened out in the surrounding air. However, in the event the airship encounters an air whirl, the stabilizer would tend to steer it into a curved path, which, in this case, would be the path of least aerodynamical yaw and which coincides with the path of least aerodynamical stress of the airship superstructure.

A clearer explanation of these characteristics can be had by reference to Fig. 1 illustrating the action of a directionally unstable airship when it is permitted to travel with neutral rudders in quiet air. Any incidental slight disturbance would yaw the airship sidewise in one direction or another and the directional path would immediately become a curve such as that indicated at 72. The center of the curve 73 is situated at a point in a plane 74 athwart the airship's bow. This is true because a circular path of flight of this kind is the only flight condition under which the equilibrium of both forces and moments would be stable. Also under these conditions of circular flight, the yaw occurs between the ship's axis and the local air flow. The angle of yaw increases from the bow to the stern of the airship. As best shown in Fig. 1, the yawmeter 21 is applied at some location where the yaw is considerably pronounced; for example, adjacent the airship stern and the yawmeter is connected to the rudder in such relation as automatically to cause a rudder inclination that restores the airship to its straight course, the forces of energization being transmitted to the servo-motor under the influence of the yawmeter.

In the event a stable airship is struck by a lateral or vertical gust, it sways about a center located in a plane athwart some portion of the airship to the rear of that of a steadily turning airship. As a rule, a gust first strikes the airship nose creating a condition similar to that wherein the local angle of yaw or of attack occurs at this portion of the airship.

My invention contemplates decreasing the angle of attack at the bow or nose of the ship by providing a second yawmeter 76 diagrammatically shown in Fig. 5, and disposed at the forward end of the airship. This yawmeter operates in conjunction with the servo-motor 38 in the same manner as the yawmeter 21 shown in this figure at the after portion of the airship. The conduits 29 and 30 are extended, as indicated at 77, to communicate with the additional yawmeter 76. The two yawmeters are connected to the servo-motor 38 in the same relation or sense, and it will be apparent that these devices compensate for atmospheric disturbances occurring at either one end of the airship or the other. Stabilizing apparatus of this type are more especially adapted to be applied to airships wherein the length of the hull is relatively great with respect to its diameter.

In the event it is desirable to control the airship independently of a stabilizer, the helmsman manipulates the steering-wheel 14. The yieldable connections 19 provide means to indicate to the helmsman when the yawmeter tends to operate the steering device. The rudder mechanism may also be divided into two-part aerofoils, the one part being adapted to be operated primarily by the stabilizer and the other to be operated independently by the helmsman. Moreover, another method of operation consists in so turning the yawmeter upon its axis by means of the connections 22 and 23 as to control the zero position thereof. When so operated the latch 26 is removed in order to permit the element 24 to be rotated. Also under these conditions the operation of the cable 69 may be discontinued by suitable means which serve to disengage actuating elements thereof. Substantially the same effect is produced by energization of the servo-motor 38 by means of the cable and pinion connections 65 and 68, under which conditions the latch is replaced and the cable 22 disconnected.

Although the type of yawmeter shown in Figs. 2 and 4 is the preferred form, it is to be understood that this invention is not limited to such types. For example, any suitable pair of devices sensitive to air flow can be located at opposite sides of the leading portion of any stream line shaped body which causes the air stream to split in such manner that the plane of symmetry of the body and its air flow elements will be sufficiently sensitive to cause a difference in the reaction of the elements to energize the servo-motor 38. Instead of employing a special form of body in which the yaw-sensitive elements are embodied, a stream line shaped portion of the airship may be employed, for example, the ship's bow 80 or the forward portion of a gondola, or a leading portion 81 of one or more fins 12. In Fig. 6, such embodiment of a yawmeter is illustrated in conjunction with the bow of the airship. Ducts 82 and 83, which correspond exactly with the ducts 27 and 28, are spaced equal distances from the plane of symmetry of the nose of the airship. The manometer 33 reacts in response to all pressure differences between the ducts 82 and 83. This pressure depends primarily upon the angle of yaw and as soon as an air current strikes the airship at a slight inclination indicated by the angle θ (Fig. 6), the pressure at the windward duct 83 is increased while the pressure at the leeward duct 82 decreases. The same conditions are true in

the event the yaw sensitive elements are located in the fin 12 as shown by Fig. 7.

The type of yawmeters above described depends upon differences in air pressure upon the forward quadrants of a streamline body for creating forces sufficient to energize the servo-motor. Another form of device which is sensitive to differences in velocity of air currents on the sides of the head of a streamline body can be employed for effecting substantially the same results. An example of this type of device shown in Fig. 8 includes Venturi tubes 84 and 85 and the forward portion or bow 80 of the streamlined body 11. These tubes are rigidly mounted closely adjacent the surface of the portion 80, which is rigidly secured to, or constitutes a portion of, the body 11. Also, the Venturi tubes are so mounted that the axis of each is substantially parallel with the nearest adjacent portion of the surface of the portion 80, and the tubes are equidistant from the leading edge, or so-called point of stagnation, of the air flow upon such streamlined surface. When the body 11 is yawed the stagnation point of the air flow upon the surface 80 shifts and the suction is diminished in the Venturi tube toward which it shifts while the suction is increased in the other Venturi tube. This difference in section causes actuation of the diaphragm of the manometer whose chambers are connected to the conduits 82 and 83 respectively.

Other devices sensitive to changes in velocity of air currents, such as electrical anemometers, may be employed.

According to modern practice, the empennage of an airship is located adjacent its stern. However, it has often been suggested that additional control surfaces be provided adjacent the bow of an airship. Experiments have been made with forwardly disposed control aerofoils, but they were abandoned because when not operated, they tended to increase the instability of the airship.

Forwardly located control aerofoils or rudders 86 are shown in Figs. 5 and 6, and by applying my invention to these devices, the disadvantages heretofore encountered with this type of rudder will be obviated. The forward rudders 86 are operated in substantially the same manner as the rear rudders 13 and are provided with struts 87 and cables 88 and 89 connected to the servo-motor 38. Because of the fact that the rudders 86 are located at the forward end of the ship, they must be actuated in a direction opposite to that in which the rear rudders 13 are operated when it is desired to steer the airship in a given direction or to stabilize it against forces of an air current tending to throw it off its course. Accordingly the cables 88 and 89 are crossed, as indicated in Figs. 5 and 6. By employing rudders at both ends of the airship, all derivative atmospheric disturbances are compensated for without imposing undesirable strains upon the hull superstructure. For example, assuming that a gust strikes the bow of the airship, the counterforce of steering is applied at substantially the location where the atmospheric disturbance occurs. Therefore, no appreciable transmission of forces through the airship superstructure results, as is the case where the stern rudders alone are employed.

Instead of providing connections to one servo-motor 38 for operating both the forward and after rudders, a separate servo-motor may be employed for each rudder. It is also to be understood that the invention is not limited in its application to rudders having flat surfaces, but it may be applied to any equivalent means for creating aerodynamical forces across the axis of the airship; for example, tiltable propellers or so called variable pitch propellers embodying laterally rotatable blades may be employed.

Although I have illustrated but the preferred forms which my invention may assume and have described those forms in detail, it will be apparent to those skilled in the art that it is not so limited but that various minor modifications and changes may be made therein without departing from the spirit of my invention or from the scope of the appended claims.

What I claim is:

1. The combination with a dirigible airship having a substantially symmetrical stream-lined portion and rudders, of a plurality of Venturi tubes disposed symmetrically adjacent the forward extremity of the stream-lined portion, the axes of the Venturi tubes being substantially parallel to the local tangent of the longitudinal genetratrix of the stream-lined portion, manometric mechanism connected to the Venturi tubes, and a servo-motor connecting said mechanism to the rudders.

2. The combination with a dirigible airship having a symmetrical stream-lined portion and rudders, of a pair of Venturi tubes disposed symmetrically at the rear of the forward extremity of the stream-lined portion, the axis of each Venturi tube being substantially perpendicular to the radius of the curvature of the stream-lined portion nearest the Venturi tube, mechanical means connected to the rudder, and means connecting the Venturi tubes to the mechanical means, said mechanical means being responsive to variations in air flow through the Venturi tubes for operating the rudders.

In witness whereof, I have hereunto signed my name.

WOLFGANG B. KLEMPERER.