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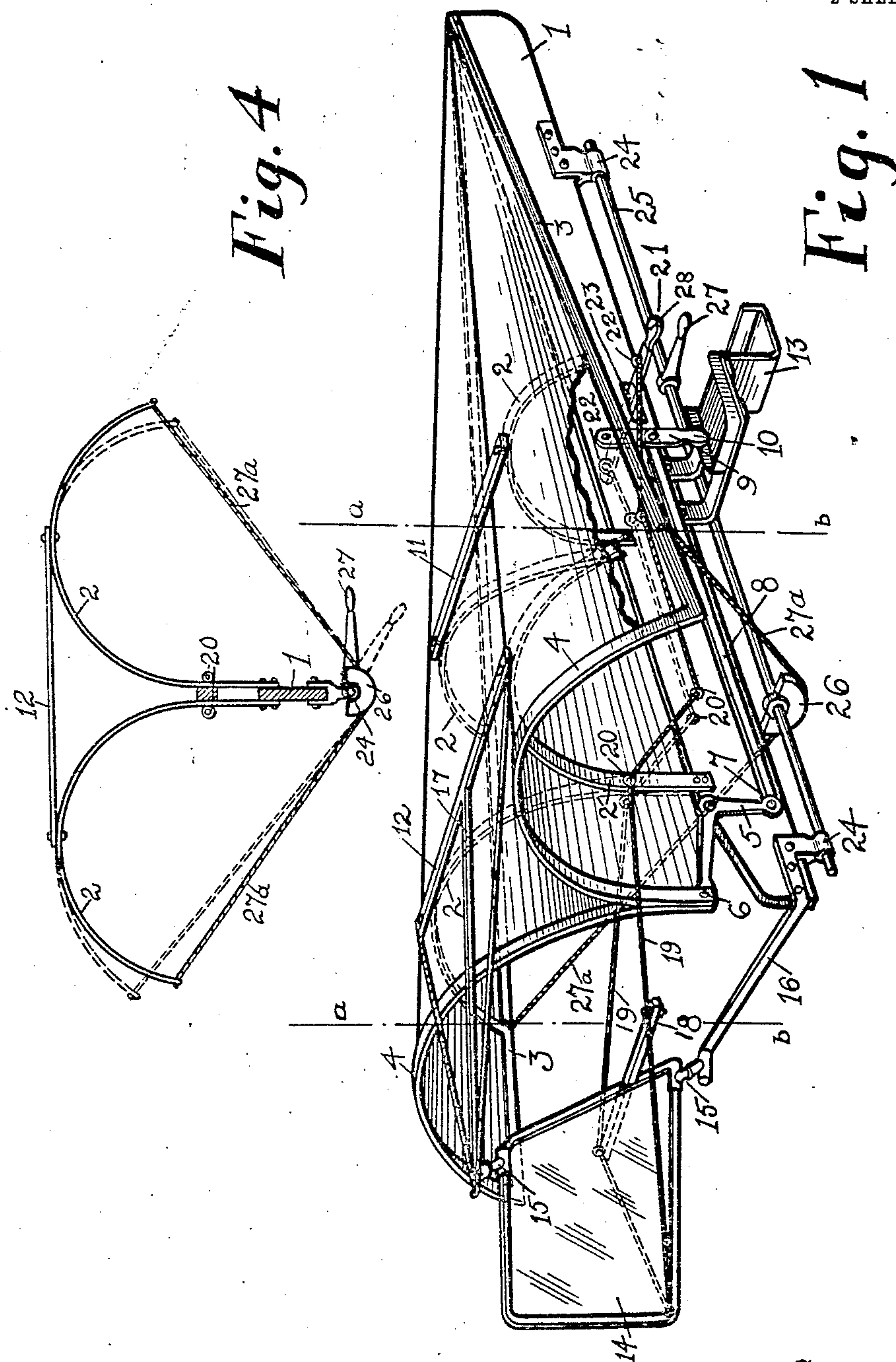
FLYING MACHINE.

APPLICATION FILED FEB. 15, 1910.

989,786.

Patented Apr. 18, 1911.

2 SHEETS—SHEET 1.



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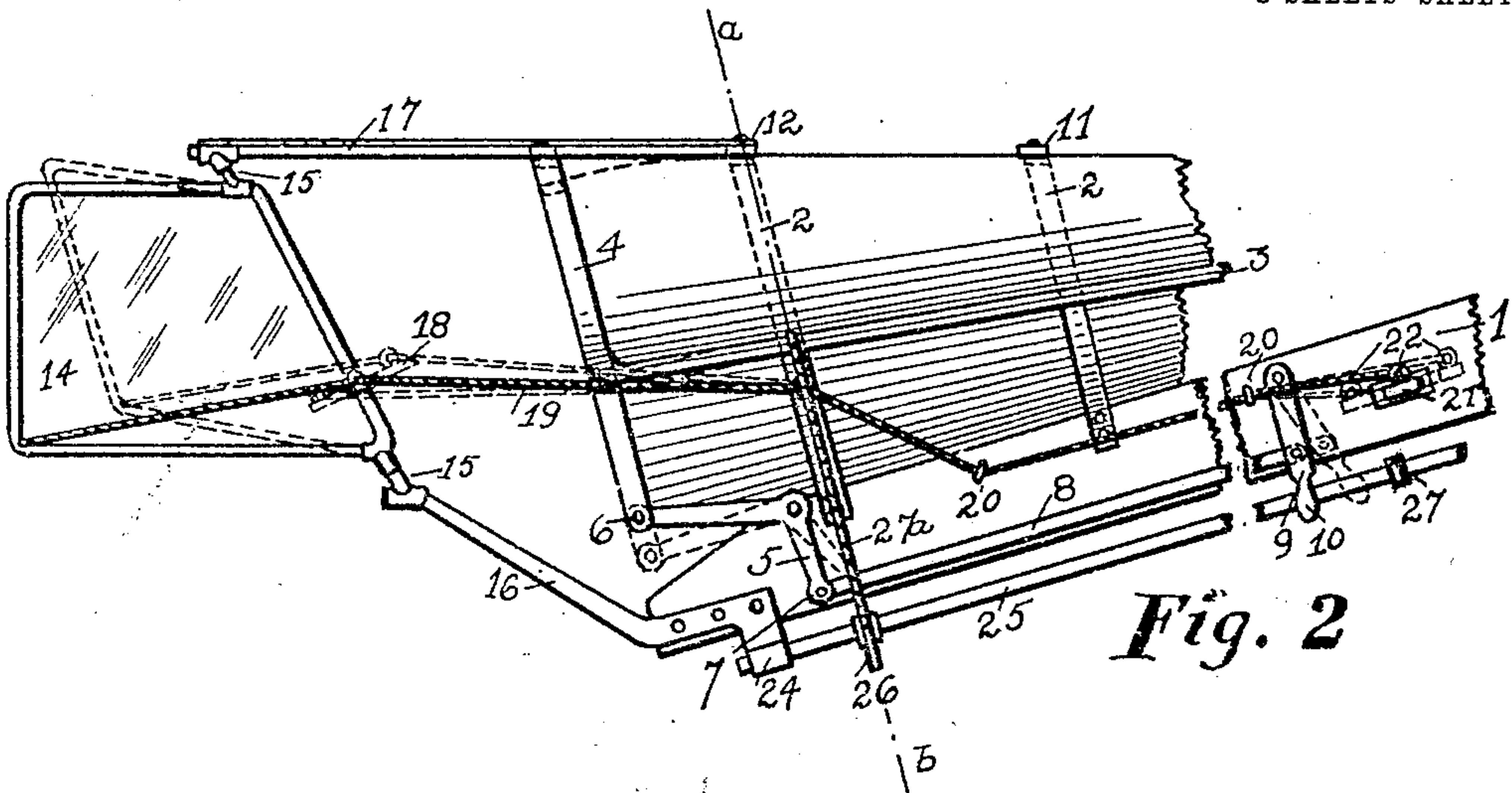


Fig. 2

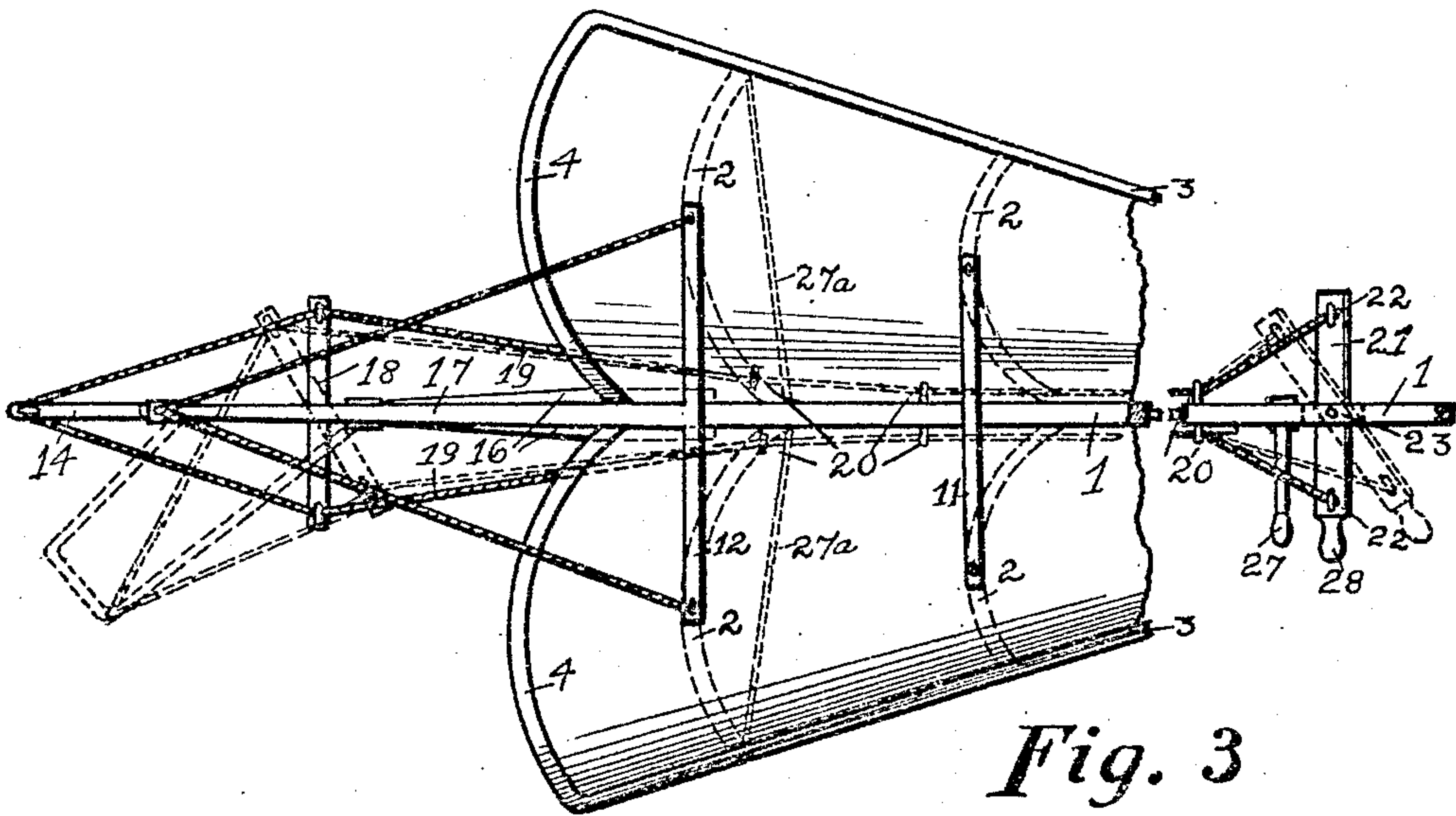


Fig. 3

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# UNITED STATES PATENT OFFICE.

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FLYING-MACHINE.

989,786.

Specification of Letters Patent.

Patented Apr. 18, 1911.

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*To all whom it may concern:*

Be it known that we, ULYSSES GRANT LEE and WILLIAM AUSTIN DARRAH, citizens of the United States of America, and both residing at 1164 Forty-fourth street, in the city of Brooklyn, county of Kings, and State of New York, have invented certain new and useful Improvements in Flying-Machines, of which the following is a specification.

Our invention relates to flying machines of the type in which the weight is sustained by the reactions resulting from the movement of one or more surfaces through the air, either by mechanical power or the force of gravity.

The objects of our invention are: 1st, to provide a supporting surface of such design that it will tend to return, automatically, to the normal position if temporarily displaced; 2d, to provide additional means for maintaining lateral stability, or for regaining the same; and 3d, to provide means for directing the machine both vertically and horizontally; and for maintaining such direction; and such other purposes as are set forth.

To accomplish these ends, our invention consists of certain novel features which are shown in the accompanying drawings, described in the specification, and then definitely pointed out in the claims.

In the accompanying drawings, Figure 1 is a perspective view of a flying machine embodying our invention in one form. Fig. 2 is a side elevation showing the devices for directing the motion of the machine. Fig. 3 is a plan view showing the mechanism for operating the vertical rudder. Fig. 4 is a section on line *a-b* showing the auxiliary means for regaining transverse equilibrium.

Our invention relates to those flying machines in which the weight is supported by the reactions resulting from the movement of one or more surfaces through the air, the said surfaces being of such shape and inclined at such an angle that the air adjacent to said surfaces is accelerated in a downward direction.

Experience has shown that it is not difficult to lift a comparatively large weight by the reaction between the supporting surface and the air, but with all types of machines which have previously been devised, it is a very difficult matter to maintain

equilibrium, requiring the constant attention of the operator.

It is the object of our invention to provide a supporting surface which, as a result of its shape, will tend to automatically regain its equilibrium if disturbed, and which will not have its equilibrium disturbed by changes of the relative velocity of the machine and the air, or by changes of direction. To best obtain these ends it is preferable, though not absolutely necessary, that the means for directing the motion of the machine be constructed as herein described.

Turning now to the drawings, Fig. 1 shows in perspective one type of surface having the features which we have discovered to be necessary to insure an automatic maintenance of equilibrium, a constant position for the center of upward pressure, and the other advantages which we claim. Our surface is built on a keel, 1, to which the ribs 2, are rigidly fastened at their lower ends. In the construction which we prefer the ribs are bent on arcs of circles, increasing in size from front to rear, so that the resultant surface is substantially cone-shaped. To the outer ends of the ribs and to the forward end of the keel, longitudinal strips 3, are attached. At the rear extremity of the surface formed by covering the framework just described with any suitable material, two floating ribs 4 are attached. The floating ribs 4, are fastened at their outer ends to longitudinal strips 3, while at their inner end they are fastened together and pivoted to the bell-crank 5, by pivot 6. The lower end of the bell crank 5, is pivoted by pin 7 to the rear end of connecting rod 8, which at its forward end is pivoted to lever 9. One end of lever 9 is pivoted to the keel 1 while the other end is formed into a handle 10. The frame composed of ribs 2 and 4, longitudinal pieces 3 and keel 1 is covered with any suitable material as for instance canvas, tightly stretched in place. Two similar sections of a conical surface are thus formed, the sections being joined together along an element at the keel. The two parts of this supporting surface are held in their relative positions by spacing means 11 and 12 which are fastened to ribs 2 and 4 at their highest points. A seat 13, is fastened to the keel for the convenience of the operator.



A rudder for steering the flying machine in a horizontal plane is shown at 14, pivoted on pins 15, the said pins being held on rods 16 and 17 which are fastened respectively to the keel and to the spacing strut 12. The axis of the rudder is situated in the vertical plane through the center of the keel. The said axis is however inclined at an angle to the vertical, sloping from the lower front end upward and backward to the rear and upper end. With the relative proportion of parts as shown in our drawings we have found 45 degrees to be a satisfactory angle though for obvious reasons we do not limit ourselves to this angle. The rudder bar 18 is fastened at right angles to the plane of the rudder through its forward edge. Rudder ropes 19, are fastened to the rudder bar 18 and pass through rings 20 to horizontal lever 21 to which the ropes are fastened by rings 22. The lever 21 is pivoted to the keel at 23. The end of lever 21 is formed into a handle at the end adjacent to the operator. Supported below the keel by bearings 24 is a rod 25 carrying a rocker 26 and a lever 27. Cords 27<sup>a</sup> are connected from the longitudinal strips 3 at points adjacent to the ribs 2 to the rocker arm and firmly fastened to the center of the rocker.

From the above description of the supporting surface, together with the drawings, it is clear that the cutting edges of said surface, or the edges which first cleave the air, extend diagonally from front to rear, substantially the length of the machine. Now it is a well established fact that the greater part of the lifting power of any surface which moves relatively to the air is concentrated within a short distance from the cutting edge. It is further well known that for different angles of inclination and for different speeds with the same inclination the position of the resultant upward pressure is very different. An approximate rule is that as the angle of inclination varies from 90 degrees (or a position perpendicular to the direction of flight) to 0 degrees (or a position parallel to the direction of flight) the center of upward pressure, varies from the geometrical center of the surface to the forward or cutting edge. A similar shifting takes place as the relative speed of the air and the surface is varied. It is understood that the above shifting of the center of pressure takes place chiefly in surfaces, the cutting edge of which is substantially perpendicular to the direction of motion. It is also common knowledge that the above described phenomena of the shifting of the center of upward pressure is due to the fact that the cutting edge supplies a larger and larger part of the total lifting power as the speed increases and as the angle of inclination decreases.

As a result of the shifting of the center of

upward pressure all flying machines employing surfaces in which the cutting edge is substantially perpendicular to the direction of flight, experience a continual tendency to dive upward or downward as the speed or angle of inclination changes. Such changes of equilibrium require the constant attention of the operator to overcome them. If, however, the cutting edge extends substantially the entire length of the surface from front to rear, any increase or decrease in the lifting force at the cutting edge will be distributed the entire length of the supporting surface with the result that the center of pressure will be substantially unchanged in position. The machine when equipped with a supporting surface of the character described is therefore stable longitudinally or about a horizontal transverse axis.

Turning now to Fig. 4 and considering the transverse stability of the supporting surface it will be seen that there are two causes which operate to return the machine to its normal position when displaced for any reason. The first cause is due to the fact that as the machine tilts over, as for example toward the left side, the projected area of the left side upon a horizontal plane increases, while the projected area of the right side decreases. Since the supporting power of any surface is proportional to the projected area, other conditions being equal, the upward force on the left side increases while that of the right side decreases with the result that the flying machine will tend to right itself. The second cause which contributes to automatic stability is due to the fact that as the surface tilts toward one side, the center of downward pressure due to the weight, is shifted to the other side, thereby creating a couple tending to right the machine. It therefore follows that a flying machine equipped with a supporting surface of the type here described is in a condition of stable equilibrium both transversely and longitudinally.

As an auxiliary means of regaining transverse equilibrium we provide the means consisting of rod 25, rocker 26 rigidly fixed thereto, and flexible connections 27<sup>a</sup> which are fastened to the rocker and to the supporting surface at the rearward end of strips 3. By turning down lever 27 as shown in the dotted lines in Fig. 4 one side of the supporting surface is pulled down while the other side is allowed to move upward, thereby accomplishing the same end as the bodily rotation of the surface about a longitudinal axis, namely decreasing the projected area on the side which has turned downward, and increasing the projected area on the side which has rotated upward, thus producing a couple which acts to restore the machine to its normal position.



In order to direct the machine in a vertical plane, and as an auxiliary means of maintaining longitudinal stability we have provided the means shown in Figs. 1 and 4.

5 The said means consists of two floating ribs 4, at the rear extremity of the supporting surface, the said ribs being fastened together at their inner and lower ends, and pivoted at this point to the bell crank 5 which is

10 connected by rod 8 to lever 9. If lever 9 be moved into the position shown in the dotted lines in Fig. 2 the bell crank will be rotated as shown, and the rear end of the supporting surface will be depressed into

15 the position shown by the dotted lines. We prefer to depend upon the flexibility of the material forming the framework of our machine to allow this deflection, though hinges or any suitable pivots may be used. The

20 deflection of the rear end of the supporting surface increases the pressure of the air upon this portion, thus shifting the center of upward pressure backward with the result that the machine will be directed downward. A movement of the lever in a reverse

25 direction will cause the rear margin of the supporting surface to be raised, with the result that the center of upward pressure will be shifted forward thus causing the machine to be directed upward. It is obvious

30 that the means of directing the machine in a vertical plane may be used as an auxiliary means of maintaining equilibrium.

Coming next to the means for directing the flying machine in a horizontal plane,

35 we have found that there are two forces which act to tend to over-turn a machine which is turning about a vertical axis. The first is the centrifugal force due to the mass

40 of the machine. Since the center of mass is below the center of upward pressure, the centrifugal force produced when the machine turns about a vertical axis will act to throw the weight outward, thus depressing

45 the side of the supporting surface, toward which the machine is turning. A slight movement in this direction is advantageous as it prevents the machine from sliding sideways through the air. There is a second

50 force which is caused by the backward travel of the center of upward pressure as the machine turns. This force acts to depress the forward end of the machine causing it to tend to dive forward.

55 The part of our invention which relates to the vertical rudder provides means for so designing the rudder that the forces upon it are sufficient in magnitude and in the proper direction to overcome the forces

60 which tend to destroy the equilibrium of the flying machine. One arrangement which accomplishes these ends is shown in Figs. 1, 2, and 3. This consists of a rudder 14 which may be most satisfactorily formed by

65 stretching any suitable covering over a

frame work of the shape shown. We have found it preferable to pivot the rudder on an axis passing through its front edge though this is not necessary. As shown in the drawings the rudder is pivoted by pins 15 on an

70 axis inclined about 45 degrees, the said axis sloping from the lower and forward edge upward and rearwardly to the upper and back edge. A cross-bar is connected to the forward edge of the rudder and to wires 19,

75 which pass through rings 20 to lever 21. Thus when lever 21 is moved to the position shown in the dotted lines in Figs. 2 and 3, the rudder is rotated as shown in the dotted

80 lines. It will be noted that the center of pressure of the rudder is above the center of weight of the flying machine. As a result, when the rudder is turned about its inclined axis its surface will deflect currents

85 of air upward and backward and will thus have a downward force upon its surface. By making the surface of the rudder sufficiently large the downward force will have a sufficient value to automatically overcome

90 the tendency of the machine to dive forward on turning. It will also be noted that as the sharpness of the turn, and consequently the tendency to dive increases, the effective angle of inclination also increases, thus automati-

95 cally correcting the diving tendency and hence automatically maintaining equilibrium. The tendency to overturn due to the centrifugal force exerted by the mass of the flying machine in turning is counteracted by

100 the side thrust of the air on the rudder due to the sideward deflection of the air when the rudder is turned. From an inspection of the figures it will readily be seen that the side thrust of the air is exerted on the side of the

105 rudder toward which the machine is turning. Since this side thrust is in the same direction as the centrifugal force but above the center of support instead of below, the two forces may be made to neutralize each other by

110 making the area of the rudder sufficient and the distance of the center of the rudder above the center of mass the requisite amount.

It will now be evident from the foregoing description that there are a number of

115 differently shaped surfaces which may have the characteristics enumerated, and which will therefore possess automatic stability both about a central longitudinal axis and

120 also about a transverse axis which is horizontal, and we do not desire to be understood to limit ourselves to any particular detail of construction.

The features which we have discovered to be necessary for automatic stability about a central longitudinal axis are as follows:—

125 1. At least one vertical surface or keel extending from front to rear of the machine, and symmetrically located. 2. Such a disposition of weight and supporting surface that the center of weight of the machine is

130



below the center of upward force of the supporting surface. The feature which we have discovered to be necessary for securing automatic stability about a transverse, horizontal axis is a supporting surface the cutting edge of which extends from front to rear either by subdividing the surface into a number of planes placed one behind the other, by a cutting edge which extends diagonally from front to rear, or some equivalent. It is a supporting surface combining these characteristics which we desire to claim and we do not wish to be understood as limiting ourselves to the exact construction described, as this is merely the form which we have found successful with relatively small machines.

Having now described the features of our invention we make the following claims. We do not wish to be understood to limit ourselves to the exact details shown as it is obvious that many modifications can be made therefrom, and still come within the scope of our invention. We do not limit ourselves to curved surfaces, though from structural reasons they are much simpler to build than plane surfaces. We include under the term "conical surface" and "substantially conical surface" as used in the following claims and in the specification, those surfaces which are composed of several individual elements or surfaces so combined that the lines of intersection of the component adjacent elements with each other, or these lines of intersection continued, converge toward the forward part of the machine. In the limiting case when the individual surfaces are made numerous enough this structure becomes a cone but we desire to include also the surface of a pyramid and of a pyramidal wedge. It is of course understood that the lines of intersection or these lines continued do not necessarily converge to a mathematical point, as a considerable variation is allowable and still secure the results of our invention. By the term "element" as used in the following claims we refer to a line situated in the lifting surface and extending from the front to the rear of said surface. In case a strictly conical surface were employed it would be the line which would generate the surface mathematically, though for obvious reasons we do not desire to confine ourselves to the single case of the mathematical element.

By supporting surfaces we refer to that surface of the flying machine which by reason of its reaction with the air sustains the weight of the machine. By the term cutting edge we refer to the edge of the supporting surface which initially enters the air.

Having now fully described our invention, what we claim as new and desire to secure by Letters Patent, is—

1. In a flying machine, the combination of a compound supporting surface, composed of symmetrical, substantially conical surfaces, concave downward and joined along an element, the outer or cutting edges of said supporting surfaces being disposed below the central elements of said surfaces, and a rudder for directing the course of the machine, the axis of said rudder being disposed in a vertical plane and inclined from front to rear.

2. In a flying machine a compound surface composed of symmetrical, substantially conical surfaces, concave downward and disposed side by side, the said surfaces converging toward the forward part of the machine.

3. In a flying machine a compound supporting surface, composed of symmetrical, conical surfaces, concave downward, and joined along an element, the outer or cutting edges of said conical surfaces being disposed below the central elements of said surfaces.

4. In a flying machine a supporting surface having substantially the shape of the surface of a segment of a cone, the apex of the cone being in the direction of the forward part of the surface.

5. In a flying machine, an automatically stable supporting surface composed of two symmetrical portions of substantially conical surfaces said surfaces being concave downward and disposed side by side, the inner edges of said surfaces being continued to form a vertical portion or keel extending longitudinally the length of the machine.

In testimony whereof, we have signed our names to this specification in the presence of two subscribing witnesses, this eleventh day of February 1910.

ULYSSES GRANT LEE.

WILLIAM AUSTIN DARRAH.

Witnesses:

FERDINAND LEE,  
ADAM HARDY.