J. S. STEPHENS.

AEROPLANE FLYING MACHINE.

APPLICATION FILED JULY 5, 1910.

**1,127,105.**

**Patented Feb. 2, 1915.**

7 SHEETS—SHEET 1.

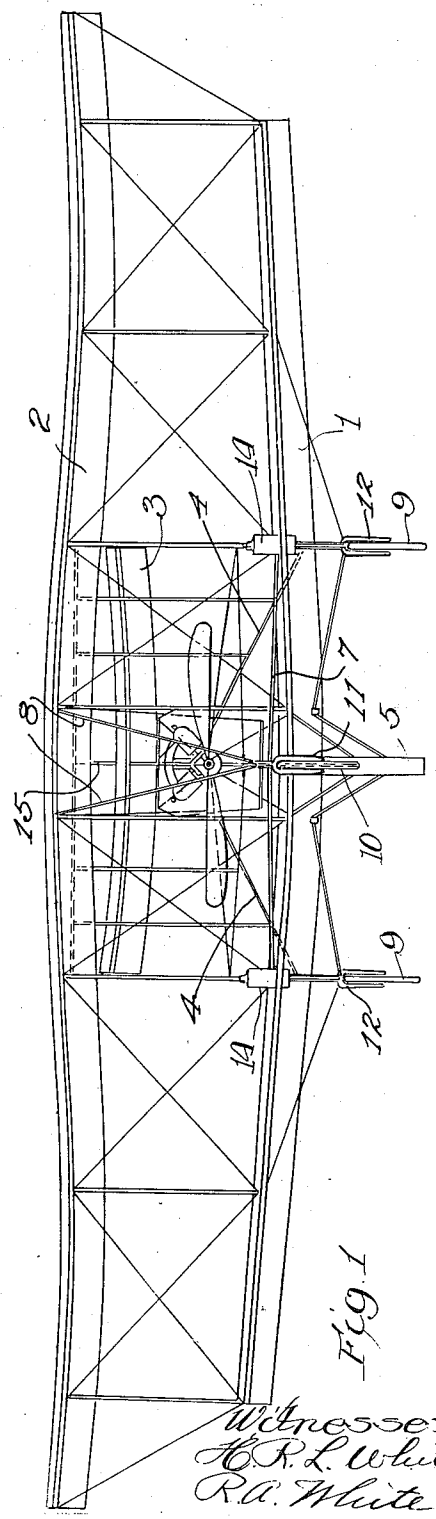


Fig. 1

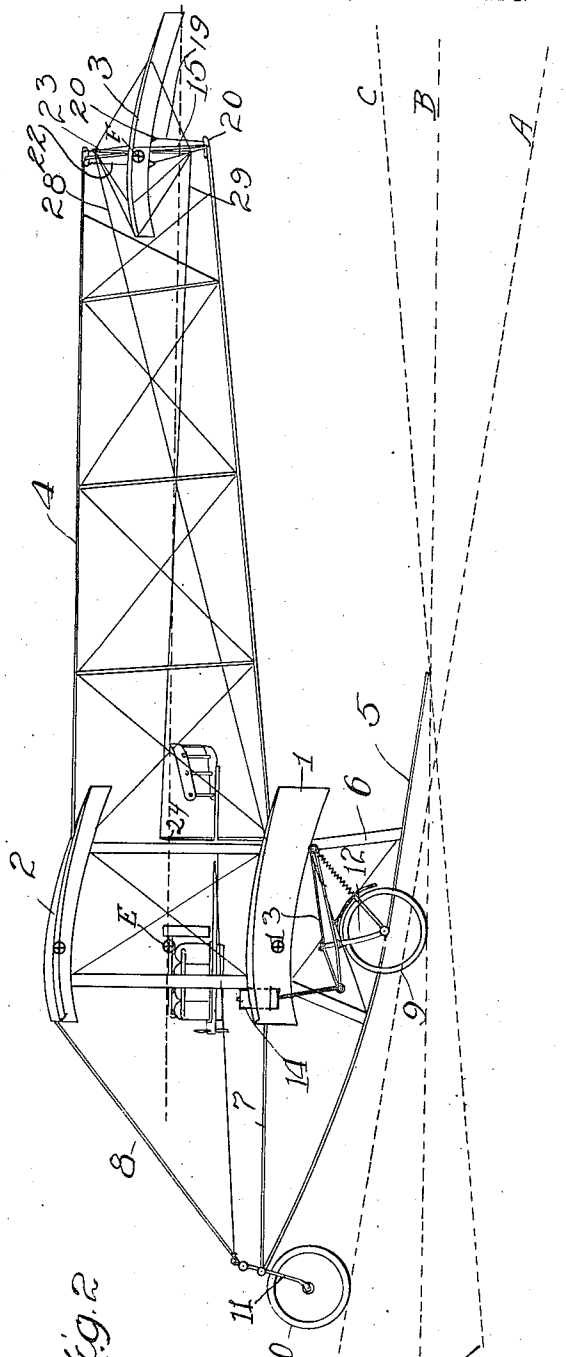


Fig. 2

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7 SHEETS—SHEET 2.

Fig 3

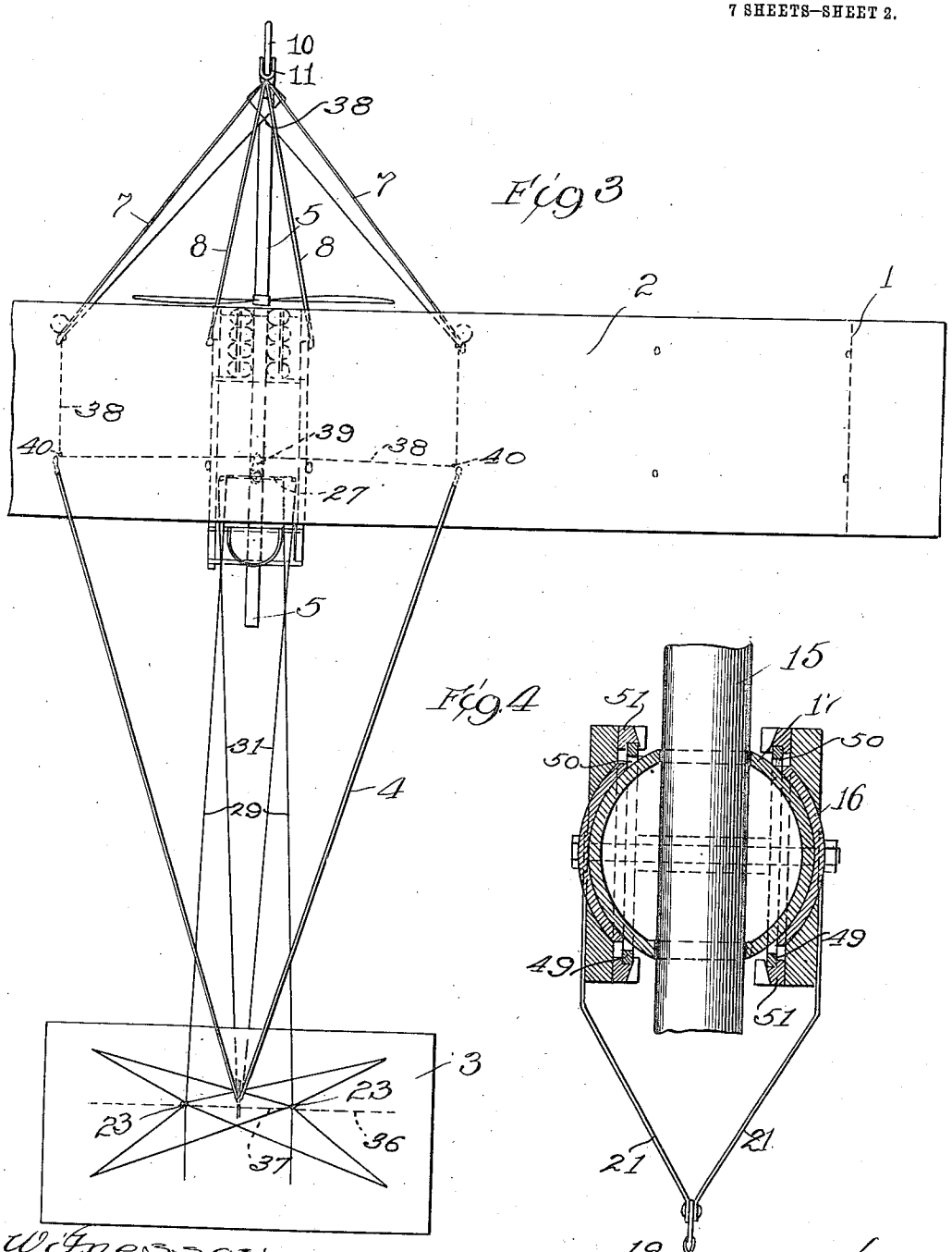



Fig 4




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7 SHEETS—SHEET 3.

Fig. 5.

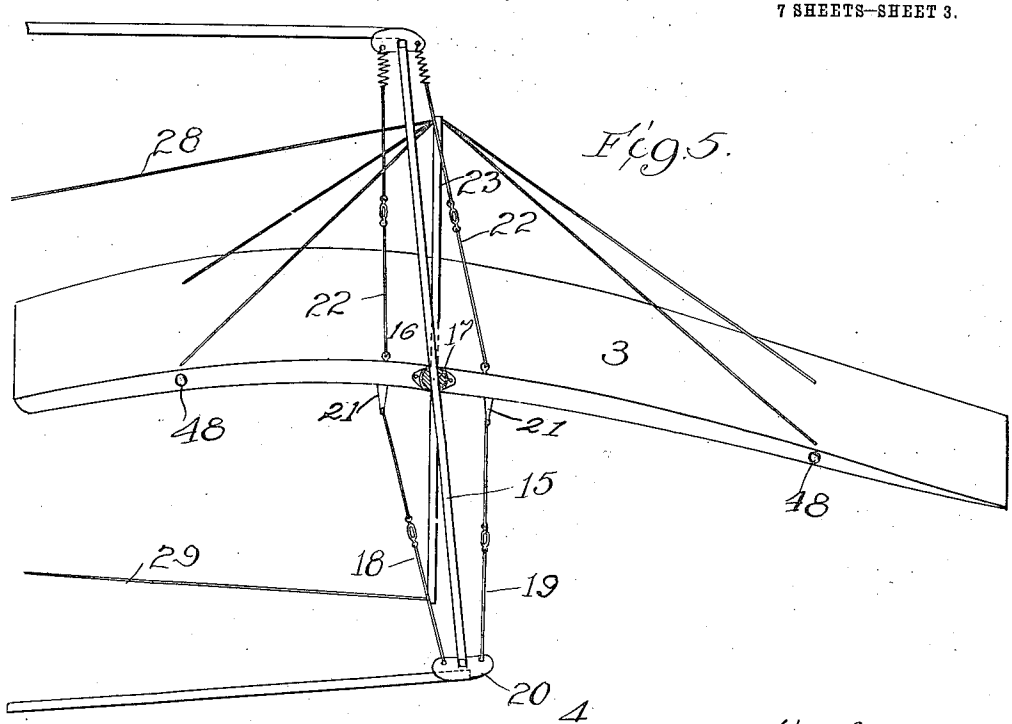



Fig. 6

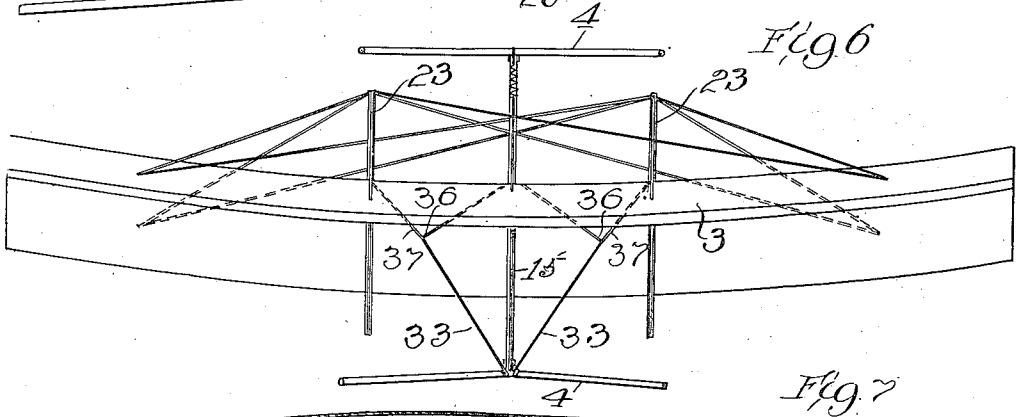



Fig. 7

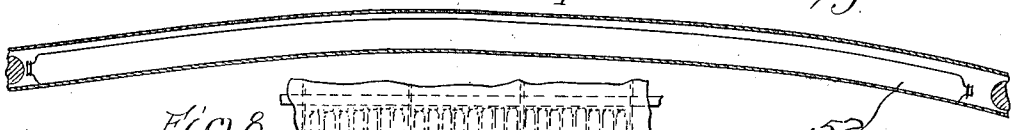
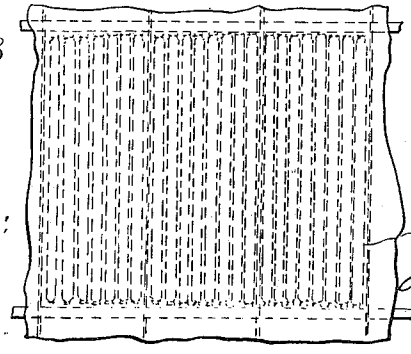



Fig. 8




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7 SHEETS—SHEET 4.

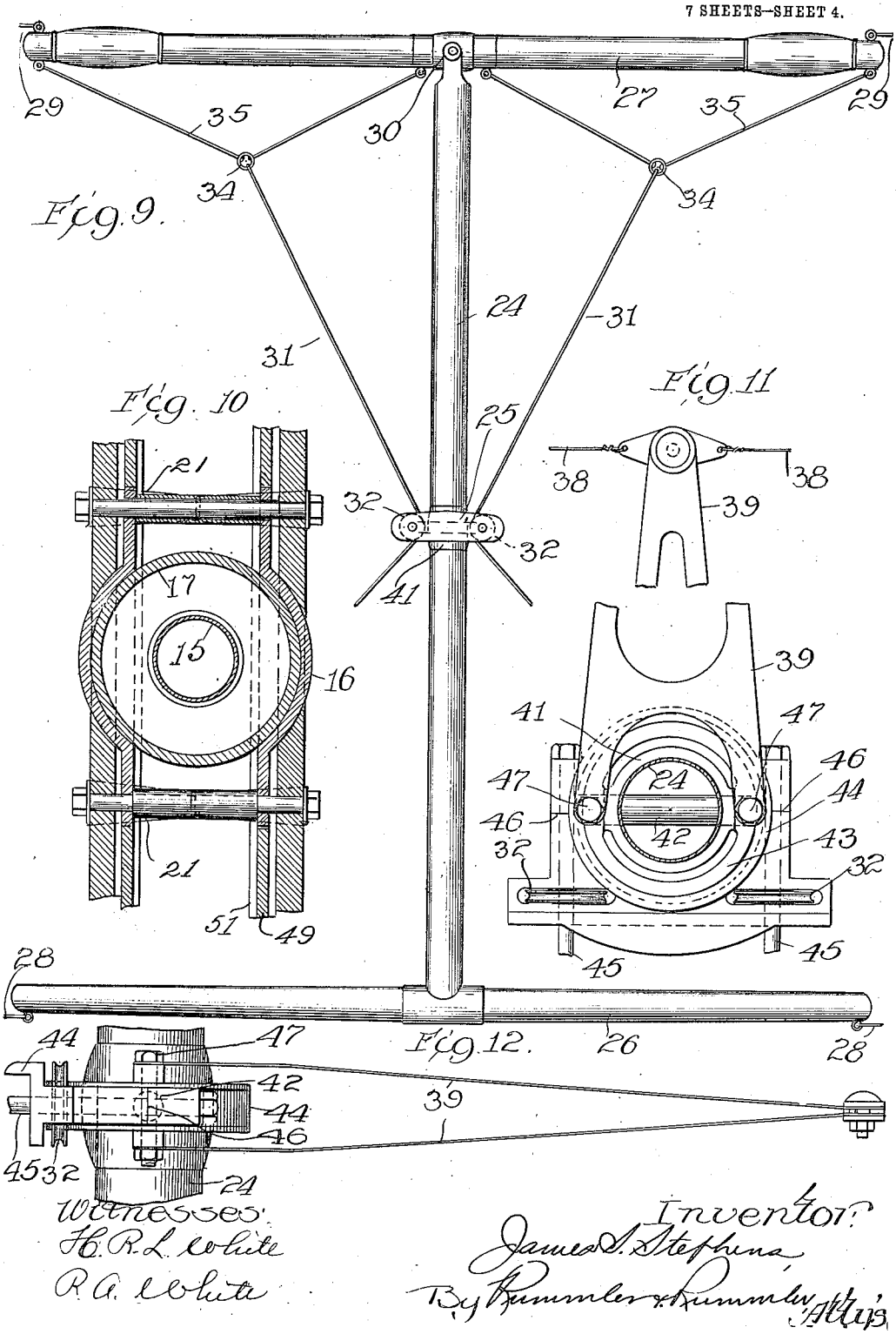



Fig. 9.

Fig. 10

Fig. 11

Fig. 12.

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7 SHEETS—SHEET 5.

Fig. 13

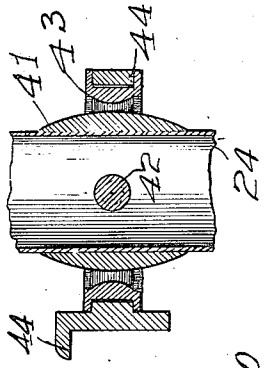



Fig. 14




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7 SHEETS—SHEET 6.

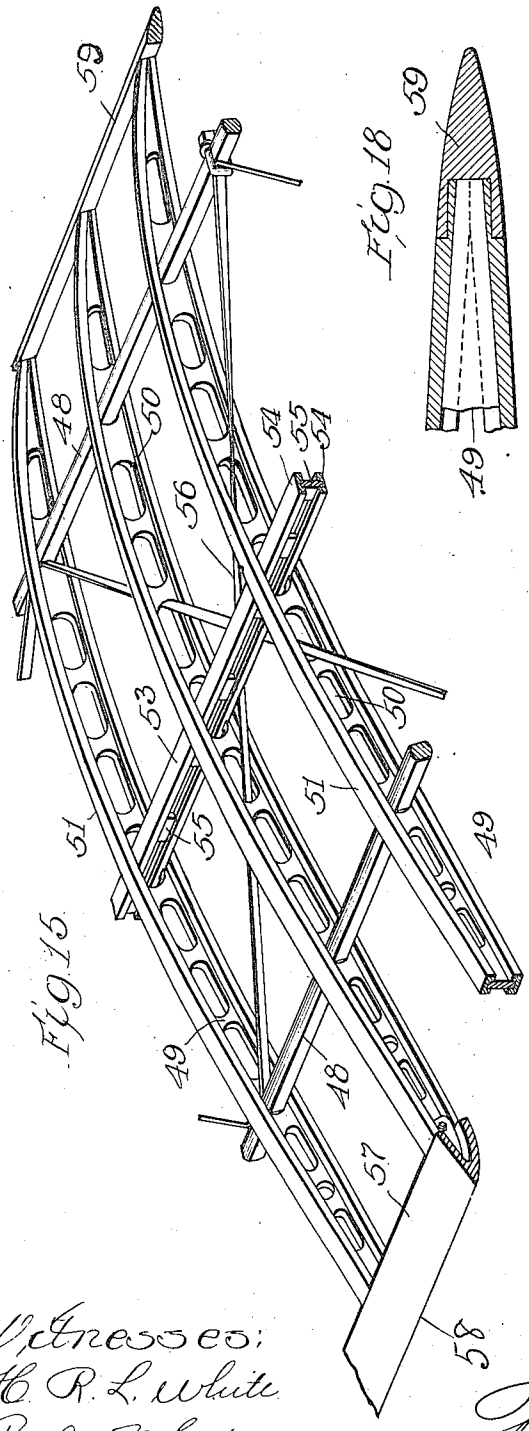



Fig. 15.




Fig. 18.

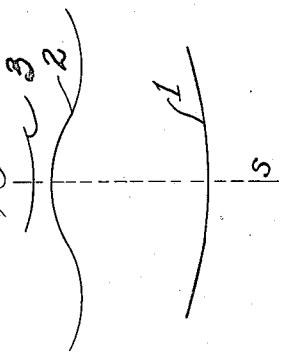



Fig. 19.




Fig. 16.

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7 SHEETS—SHEET 7.

Fig. 17

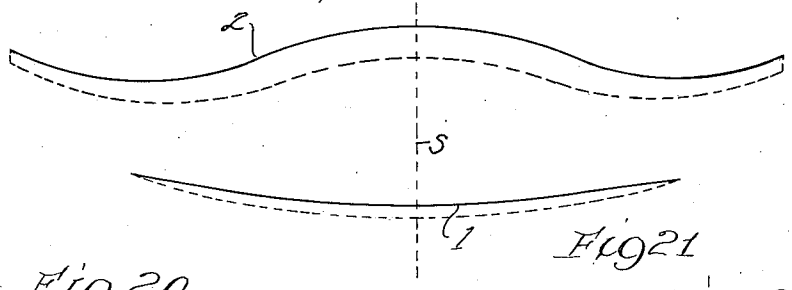



Fig. 20

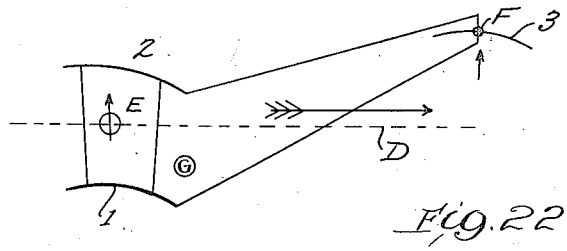



Fig. 21

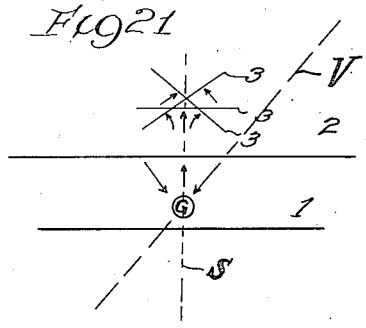
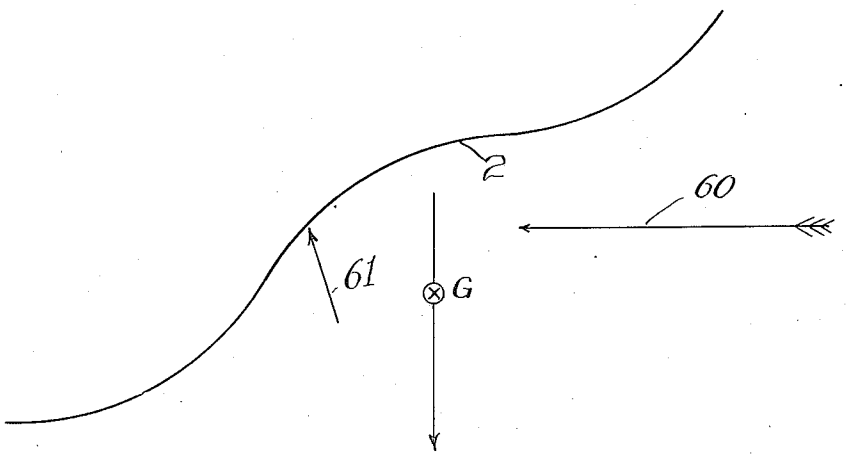



Fig. 22




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# UNITED STATES PATENT OFFICE.

JAMES S. STEPHENS, OF CHICAGO, ILLINOIS.

## AEROPLANE FLYING-MACHINE.

1,127,105. Specification of Letters Patent. Patented Feb. 2, 1915.

Application filed July 5, 1910. Serial No. 570,419.

*To all whom it may concern:*

Be it known that I, JAMES S. STEPHENS, a citizen of the United States of America, and a resident of Chicago, county of Cook, State of Illinois, have invented certain new and useful Improvements in Aeroplane Flying-Machines, of which the following is a specification.

The main objects of this invention are to provide an improved form of aeroplane flying machine in which steering in any direction may be accomplished by relative movements of parts of the supporting aeroplane surfaces; to provide an improved form of steering aeroplane adapted to be adjusted to control the movements of the flying machine in any direction: to provide improved means whereby all of the operations necessary for steering laterally, vertically, or maintaining longitudinal or lateral balance may be accomplished by the movement of a single controlling member; to provide an improved form and arrangement of the supporting aeroplane surfaces of flying machines, which will avoid the necessity of vertical rudders, fins, keels, or similar constructions, which do not cooperate directly in the support of the machine; to provide an improved shape for aeroplanes whereby the air pressure will be so distributed as to compensate for disturbances of lateral balance and tend to automatically correct the same: to provide an improved construction and location of the steering aeroplane whereby it will serve to maintain lateral balance of the machine besides controlling the direction of movement thereof: to provide an improved formation for the advancing edge of an aeroplane: and to provide an improved form and arrangement of the aeroplane surfaces in biplane constructions whereby the efficiency of the supporting surfaces will be increased and whereby the effective area of the supporting surfaces will be reduced as the speed increases.

An illustrative embodiment of this invention is hereinafter described and is shown in the accompanying drawings, in which:—

Figure 1 is a front elevation of an aeroplane flying machine of the bi-plane type, constructed according to this invention. Fig. 2 is a side elevation of the same, showing the same in the normal attitude of flight, the lines A, B and C representing a horizontal surface corresponding to the respective attitudes of the machine when at rest on the ground, when in flight and when commencing to alight, it being understood that the rear wheels will yield under the weight of the machine and touch the line A when the machine is at rest. Fig. 3 is a top plan partly broken away. Fig. 4 is a sectional detail of the ball and socket joint on which the steering plane turns. Fig. 5 is an enlarged sectional detail, showing the method of mounting the steering aeroplane. Fig. 6 is a front elevation of the steering aeroplane, the adjacent parts of the supporting frame being shown in section. Fig. 7 is a detail showing the air bags between the upper and lower coverings and the frame members of the main supporting aeroplanes. Fig. 8 is a fragmentary top plan illustrating the same feature. Fig. 9 is a detail of the main controlling lever and its rocking handle bar. Fig. 10 is another sectional detail of the joint shown in Fig. 4. Fig. 11 is a detail in top plan of the joint which supports the operating lever, showing in connection therewith the tiller arm which causes the steering of the machine when supported on its wheels. Fig. 12 is a side elevation of the same viewed from the right of Fig. 11. Fig. 13 is a sectional detail of the same taken on a plane parallel with that of Fig. 12 and passing through the center of the joint. Fig. 14 is a diagram showing in isometric perspective the arrangement of the steering devices. Fig. 15 is a detail in perspective showing the method of building up the framework of the aeroplanes. Fig. 16 is a diagrammatic front elevation showing the lateral curvature of the upper aeroplane, and also showing the variation in the inclination of the fore and aft elements of the surface whereby the middle part of the plane has a greater angle of incidence to the air than do the lateral extremities, the full lines indicating the shape of the front edge of the plane and the dotted line indicating the shape of the rear edge thereof. This figure shows the plane in such position that when it is advanced horizontally the lifting effect of the middle portion is counteracted by the depressing effect of the end portions, the effect of gravity being neglected. Fig. 17 is a similar view of the same turned to such position that its entire lower surface will provide lifting effect in horizontal flight, also indicating the lower plane. Fig. 18 is a sectional detail of the

joint between the ribs and the rear edge of the frame member of the aeroplane construction illustrated in Fig. 15. Fig. 19 is a diagram showing by singe lines the differences in the lateral curvature of the planes in the biplane construction illustrated. Fig. 20 is a diagram illustrating the advantage of placing the steering plane above a line extending, in the direction of flight, through the center of effort of the front planes, such a line being represented at D. Fig. 21 is a diagrammatic front view illustrating how the leverage of the steering plane may be utilized for maintaining lateral balance when placed above a line through the center of effort of the front plane and parallel with the direction of flight. Fig. 22 is a diagram illustrating the tendency of the upper plane to assume a position of equilibrium.

In the specific construction illustrated in the drawings, the support of the machine on the air is accomplished by the main aeroplanes 1 and 2 acting in conjunction with the steering plane 3. These planes are curved in the fore and aft direction in the usual manner to provide a downwardly concave lifting surface. The surface of each of the planes is so formed as to be symmetrical with respect to a vertical plane of reference extending fore and aft through the middle of the machine, which plane will hereinafter be referred to as the plane of symmetry. (See line S, Fig. 19).

The parts of the plane 1 which are at opposite sides of the plane of symmetry are in dihedral relation to each other, being inclined upwardly and away from the center line.

The plane 2 is of downwardly diverging dihedral form at its middle part, and its lateral curvature changes so that its end portions are of upwardly diverging dihedral form. The degree of lateral curvature of the middle portion of the plane 2 is substantially the same as that of the middle portion of the plane 1, and this curvature is carried to about the same extent in each plane. The end portions of the plane 2 are of reverse curvature, while the end portions of the plane 1 are substantially straight in the lateral direction.

The inclination of the fore and aft elements of each of the planes 1 and 2 varies, being greater at the middle than at the ends. The planes 1 and 2 are rigidly connected together by a suitable truss, and disposed in such relation that the upper plane will at all times have a greater angle of incidence than the lower plane. This, together with the fact that the upper plane is extended laterally beyond the ends of the lower plane, serves to neutralize the effect of the deflection of the air by the lower plane, and to compensate for the reduced speed of the current of air below the upper plane due to the resistance offered by the parts of the machine between the planes. This serves to increase stability and to equalize the actual lifting effect of both planes. Stability is also increased by having the lifting effect greater in the middle than at the ends of the planes. On account of this twist, or warp in the planes 1 and 2, the effective area of the supporting surface of the machine will be gradually reduced as the machine tilts forward, thus permitting the effective area of the supporting surface to be adjusted to suit the speed of advance and permitting horizontal flight at different speeds. This twist is best seen in Fig. 17, in which the front edges of the planes are represented diagrammatically by full lines and the rear edges by dotted lines. From this figure it will be seen that the machine may be tilted forward, until the only effective supporting surface will be the middle portion of the upper plane. The lateral portions of the steering plane 3 are also disposed in dihedral relation to each other with respect to the fore and aft plane of symmetry and are inclined upwardly similarly to those of the plane 1.

The body frame of the machine comprises the supporting frames of the main aeroplanes 1 and 2, the bracing between them and a rearwardly extending frame or fuselage 4. Rigidly braced below the body frame is a long skid 5, the rearward portion of which extends a considerable distance beyond the rearward braces 6, and acts as a spring to yieldingly engage the ground to check the advance of the machine as it alights. The skid 5 curves upwardly at its front end where it is suitably braced by a truss structure represented by the members 7 and 8 (Figs. 2 and 3). In the drawings, the truss constructions are represented more or less diagrammatically, no attempt being made to show the details of the joints, and in some places the bracing is omitted in order to avoid confusion of the drawings. From Fig. 3 it will be seen that there is but one skid 5, and that the front and rear portions of the body frame are triangular in plan.

The alighting gear comprises, besides the skid 5, a set of wheels, of which in the form shown there are three, that is, a pair of rear wheels 9 and a front steering wheel 10, mounted in a fork 11 at the front of the body frame and elevated a considerable distance above the wheels 9 when the machine is in the normal attitude of flight, as represented in Fig. 2 with reference to the line A as the horizontal.

The wheels 9 are carried by forks 12 journaled on vertically disposed axes in swinging frames 13 hinged at their rearward ends and having their forward ends cushioned against upward movement by means of air

cushions indicated by the cylinders 14, but not shown in detail.

The steering plane 3 has ball and socket connection with the rearward upright 15 of the body frame, as detailed in Figs. 4 and 10, the socket members 16 being rigidly connected to the framework of the plane 3 and the ball 17 being longitudinally slidable on the upright 15. The upward movement of the plane 3 is limited by means of two braces 18 and 19, which are located below the plane 3 at opposite sides of the ball 17 in the fore and aft plane of symmetry, their lower ends being secured to a fitting 20 on the body frame and their upper ends being secured to depending arms 21 connected to the framework of the plane 3. These arms might be termed fulcrum arms since under certain conditions of flight their points of connection to the stays 18 and 19 serve as fulcrums about which the plane 3 turns, as will hereinafter appear. A pair of spring stays 22 are located above the plane 3 in the fore and aft plane of symmetry and respectively in front of and behind the brace 15 to support the weight of the plane 3 when the machine is at rest.

The steering plane 3 is rigidly braced and trussed as indicated in Figs. 5 and 6, and its truss comprises a pair of uprights or masts 23 which are spaced apart and in such positions with respect to the center of the ball 17 that their ends are all substantially in the same plane with said ball and symmetrically located with respect thereto.

The operating mechanism by which the steering plane is controlled comprises a lever post 24 mounted in a fitting 25 which permits it to rotate about its own axis and to oscillate in a fore and aft plane parallel with the plane of symmetry of the machine. The post 24 has a cross-bar 26 at its lower end and a handle-bar 27 at its upper end. The cross-bar and handle-bar are of substantially equal length and connected to the post 24 at their middle points, and their extremities are respectively connected with the extremities of the masts 23 of the plane 3 by cables 28 and 29, the cables which are on the same side of the fore and aft plane of symmetry of the machine being crossed as shown in Fig. 2. Thus, a fore and aft oscillation of the post 24 will cause an equal angular movement of the uprights 23 in the reverse direction and tilt the steering plane 3 for steering up or down. Rotation of the post 24 about its own axis will cause a similar and equal angular rotation of the plane 3. The handle-bar 27 is pivotally connected at 30 to the post 24, the axis of the connection 30 being at right angles to the axis of oscillation of the post 24. Cables 31 connect opposite sides of the handle-bar 27 to opposite sides of the steering plane 3. The cables 31 pass over sheaves 32 and 33, which are respectively located as close as possible to the center of movement of the post 24 and to the axis of the strut 15, so that the cables 31 will not be affected by the normal rotation of the pot 24 during steering operations, but will only be affected by the rocking of the handle-bar 27 upon its pivotal connection 30. In order to have the cables 31 lead in a direction substantially tangent to the arcs of travel of their points of construction with the handle-bar 27 and the plane 3, their ends are secured to rings 34 connected with the handle-bar 27 by braces 35, and rings 36 connected with the plane 3 by braces 37.

Turning of the steering wheel 10 for guiding the machine on land is accomplished by a pair of cables 38 connected with a tiller 39, which is rigidly secured to the rotatable gimbal ring in which the post 24 is pivoted. The post 24 may thus be oscillated in a vertical plane without affecting the tiller, but when the post 24 turns about its axis, the tiller turns with it. If the tiller 39 extends in a forward direction, as shown, then the cables 38 should be crossed so that the operation of the steering handle-bar will be the same for steering on land as for steering sidewise in the air.

A form of joint suitable for supporting the post 24 and permitting of the necessary movements thereof is illustrated in detail in Figs. 11, 12 and 13. A bearing-collar 41 is fixed at the middle of the post 24 and a pivot bolt 42 extends through the collar 41 and post 24, and has its ends seated in a gimbal ring 43 which is journaled at its periphery in a fitting 44 secured to an adjacent part of the body frame of the machine by the bolts 45, which also serve as axles for the sheaves 32, which are housed within slots in the fitting 44, as shown in Fig. 11. The fitting 44 forms a band which embraces and serves as a bearing for the ring 43, and for convenience of assembling, the fitting 44 is split on the line 46, the two parts being held together by the bolts 45. The bolts 47 which secure the tiller 39 to the ring 43 extend through holes in the ends of the bolt 42, as will appear from Figs. 11 and 12, and thereby lock said bolt 42 against shifting.

The framework of the aeroplanes also comprises novel features of construction, as will appear from Figs. 15 and 18. In the form shown, each aeroplane comprises two or more main spars 48 extending transversely to the line of flight from end to end of the plane. These are spaced apart, one behind another. In addition to the main spars 48, the framework comprises a series of ribs 49 extending transversely to the spars 48, and preferably parallel with the plane of symmetry of the machine. Each of these ribs is of I-section and has a web

formed of thin sheet material, preferably one which combines lightness with great stiffness. A suitable material for this purpose is the paper compound which is commonly called vulcanized fiber. These sheets are cut to conform with the fore and aft sectional shape of the planes at their respective localities, and are provided with perforations fitting the spars 48 and with additional perforations 50, to reduce the weight by cutting away material which is not essential to the necessary strength. The upper and lower edges of these webs of fiber are reinforced by strips or beads of wood 51, which are slotted to receive the edges of the web, and are secured in position by means of glue, or other fastening. By this construction, a rib of I-shaped transverse section is produced which has great strength in proportion to its weight.

In large machines, where the spars 48 are widely separated, one or more additional transverse members 53 may be provided. Such an additional transverse member is shown in Fig. 15. This member is built up of upper and lower wooden strips or beads 54, with an open web 55 formed of vulcanized fiber as in the rib construction. The strips 54 are grooved lengthwise to receive the web 55 which braces them apart, and are grooved transversely in their respective upper and lower surfaces to fit the webs of the ribs to brace them laterally. In the construction shown, the transverse member 53 extends through the lightening holes in the ribs. The diagonal bracing is preferably formed of flat wire 56, similar in cross-section to a clock spring, and is twisted so that at the intersections the braces will lie flat, one upon the other.

The frame members 57, which extends along and gives stiffness to the front edge of the aeroplane, is preferably of triangular shape so as to present a sharp edge 58 to the air, and is hollowed out as shown, for the sake of lightness. The upper surface of the member 57 is flush with and forms a continuation of the upper surfaces of the ribs 49. The lower surface of the member 57 is flush with the lower surface of the ribs 49 at its rearward edge, and is curved sharply upwardly so as to meet the upper surface at the edge 58. By this construction, all of the air which impinges against the member 57 in flight is deflected downwardly and increases the lifting pressure on the lower surface.

The upper and lower beads of each rib are brought together at the rearward end of the rib, as illustrated in Figs. 15 and 18, and are then together shaped to cylindrical form so as to fit a cylindrical bore in the member 59 which connects the rearward ends of the ribs. The web 49 of vulcanized fiber is also preferably extended to the end of the rib so as to give strength to the cylindrical end parts which engage the member 58.

In order to give sufficient buoyancy to the machine, in case it alights upon the water, to support the engine clear of the water, sections of inflated pig gut are packed into the spaces between the frame members and the upper and lower coverings of the planes 1 and 3. These are indicated at 52 in Figs. 7 and 8.

The operation of the device shown is as follows:—The machine rests on the ground in the attitude indicated in Fig. 2 with reference to the line A as the horizontal, and when it is in this position, its planes are so disposed as to be neutral as regards lifting effect, and therefore offer minimum resistance to advance of the machine along the ground. In starting, the machine is first driven along the ground, and as soon as it acquires sufficient speed, the operator tilts the steering plane forward so as to depress the tail of the machine slightly, giving lifting effect to the main planes, and causing the machine to rise from the ground. As the machine commences to rise, the load on the rear wheels will become gradually less, and these wheels will accordingly be pushed downward by the compressed air in the cylinders 14, and prevent the rear end of the skid from striking the ground. When the machine is flying horizontally, its normal attitude is that shown in Fig. 2, with reference to the line B as the horizontal. It will be noticed that when the machine is in this attitude, the steering plane 3 is located at considerable height above the horizontal plane extending through the resultant center of effort of the planes 1 and 2. This center in the particular design shown is located approximately at the point E in Figs. 2 and 20. This relation of the aeroplanes is best understood from the diagrammatic views 19 and 20. From these views it will be seen that when the resultant pressure on the steering plane 3 is directed toward either side of the plane of symmetry of the machine, it exerts a force tending to turn the machine around an axis extending through the center of effort E of the main plane and parallel with the line of flight, which force is utilized in the herein described invention for maintaining lateral balance of the machine, and correcting a tendency of the same to tip, whatever may be the cause of such tipping.

In view of the absence of vertical fins, rudders, keels and like structures, tending to prevent the steering plane from moving edgewise in a lateral direction, steering in horizontal directions with the device shown is accomplished in a manner entirely different from that of usual forms of aeroplane flying machines, where horizontal

steering is accomplished by vertical rudder surfaces. In the type of machine which is herein shown, and in the absence of vertical rudder surfaces, the turning of the steering plane causes the machine to turn in a direction opposite to that which would be the case if the steering were accomplished by a vertical rudder surface, and the tipping of the machine, due to the fact that the lifting effect of the main planes is less on the side thereof which is traversing the arc of least radius in turning a curve, is counteracted by the leverage of the steering plane due to its location above the line D of Fig. 20, so that the correction for disturbance of lateral balance during turning is mainly accomplished automatically by the steering plane itself, without relying upon the use of ailerons or wing warping devices, which are resorted to in usual constructions. The lateral tilting of the aeroplane 3 by tilting the handle-bar 27 enables the operator to increase or decrease the balancing effect so as to correct any disturbance of lateral balance which is not corrected automatically by the turning of the steering plane about its vertical axis.

In the form of machine shown in the drawings, the center of effort E of the main planes 1 and 2, the center of effort F of the steering plane 3, and the center of gravity G of the machine and its load are all in the fore and aft vertical plane of symmetry of the machine, the center F being above and also spaced horizontally away from the center E, and the center G being below the center E and between the centers E and F. Such an arrangement insures inherent stability and renders effective both the steering and balancing functions of the steering plane. When the steering plane is above a line drawn through the center of effort E, and parallel with the direction of flight, it will tend to come down into the plane of flight represented by the line D of Fig. 20, but this tendency is counteracted by the lifting effect of the plane 3, and there is thus available for control a positive leverage.

To steady the lateral sliding of the steering plane, which is relied upon for steering purposes, and also to assist in giving the machine inherent stability tending to keep it upright under all conditions, the steering plane, in the form shown, has its lateral side portions inclined dihedrally with respect to each other, the inclination being upward and away from the fore and aft vertical plane of symmetry. This dihedral formation of the steering plane provides a certain amount of lateral drift or resistance to edgewise motion, which, while not sufficient to render ineffective the steering principle which is relied upon and which has been hereinbefore described, reduces the lateral movement to a desirable extent and prevents sudden shifting movements of the machine, which occur in machines having planes which are straight laterally from end to end.

During flight the lifting effect of the steering plane 3 is transmitted to the body frame through one or both of the stays 18 and 19, depending upon whether or not the strain is removed from one of them by a strain upon the cables 28 or 29. These stays, being respectively fore and aft of the center of effort of the plane, determine its normal fore and aft inclination. They are adjustable, and the plane may therefore be set to what is found by experience to be the best angle for any particular design of machine. A strain upon the cables 28 and corresponding slackening of the cables 29 causes a slackening of the forward stay 18 and causes the rearward stay 19 to carry the entire upward pull of the plane 3. Similarly, a strain upon the cables 29 shifts the load to the forward stay 18. The fact that the stays 18 and 19 are connected to the plane 3 at points below the center of effort of the plane 3 insures that under normal conditions this plane will assume its normal position with respect to the plane of symmetry of the machine, and will not have a tendency to tip laterally in either direction, except when such lateral tipping is produced by tipping of the handle-bar 27. In order to provide suitable points of attachment for the stays 18 and 19, the framework of the plane 3 is extended to the desired position below the center of effort by means of the arms 21.

In order to provide inherent lateral stability for the main aeroplane structure, each wing of the upper plane is of ogee or cyma curvature laterally, and the lower plane is of dihedral form, the lateral wing portions of the latter being inclined upwardly and away from the plane of symmetry. The middle portion of the upper aeroplane 2 is of downwardly diverging dihedral form, but its lateral extremities are of upwardly diverging dihedral form. These upwardly turned lateral extremities of the upper plane 2 insure that in case the machine tips toward one side and tends to glide sidewise, it will glide toward the low side and be swung toward its normal horizontal position by the rudder effect of the upturned advancing edge of the plane. Thus, as the center of gravity is below the resultant center of effort of all the planes, the machine will naturally assume an upright position.

The center of gravity should be so placed with respect to the centers of effort of the supporting aeroplanes that the machine will normally assume a forward gliding angle as soon as the driving power of its engine ceases.

The inherent lateral stability of an aero-

plane having a lateral curvature similar to that of the plane 2, and carrying weight so that the center of gravity is below the aeroplane, will be understood from a consideration of Fig. 22, in which the aeroplane is shown tilted toward one side, and the center of gravity is represented at G below and in the plane of symmetry of the aeroplane. On account of the inclination of the plane, it will glide in a downward direction toward the left, but on account of the curvature of the plane, it will be swung toward a horizontal position. This movement is still further assisted by the fact that the left-hand side of the plane is presented to the upward pressure of the air at a more effective angle than the right-hand side, and the resultant upward pressure of air will therefore be at a considerable distance at the left of the middle line of the plane, as for instance, at the point represented by the arrow 61. As soon as the plane returns to its horizontal position, its form will tend to hold it in equilibrium, as the strongest upward pressures will be concentrated at the middle, and any departure from the horizontal position immediately brings into action the stabilizing power of the upwardly curved ends.

In addition to the stabilizing influences which are inherent in the various planes by reason of their form and relative location, there is, in the construction shown, the very important stabilizing property of the steering plane which is controllable by the operator, namely, the lateral tilting of the steering plane by tilting of the handle-bars. The effect of this tilting is obvious from Fig. 21, if one bears in mind the fact that the pressure of air against a surface is normal to the surface. From Fig. 21 it will be seen that when the steering plane is in its normal position, as indicated by the horizontal line, the resultant pressure on it is directed upward in the plane of symmetry of the machine, but when it is tilted toward either side, the pressure, as indicated by the small arrows in Fig. 21, is directed toward the corresponding side, and as these resultant pressures act at a distance from the line extending through the center of effort of the main planes in the direction of the line of flight, the steering plane will, when tipped sidewise, in one direction, tend to counteract any tendency of the machine to tip in the opposite direction. The fact that this lateral tilting is controlled by the mere rocking of the handle-bar by means of which the operator accomplishes the normal steering function, makes the control of the machine extremely simple. The operator turns the post 24 in the direction in which he wishes the machine to turn. This, as has been described, causes the turning of the machine. The disturbance of lateral balance which results in turning, from the fact that one side of the main plane travels in an arc of shorter radius, and therefore at slower speed than the other side, is off-set by the lateral pull of the steering plane, by virtue of its position above the center of effort of the main plane. But this corrective influence of the steering plane may be slightly insufficient or slightly too great to exactly balance the tendency of the main plane to tip, and in this case, the operator merely tilts his handle-bar sidewise enough to counteract such insufficiency or excess.

As has been described, the universal joint about which the steering plane turns is located substantially at or near the normal center of pressure of the air on said plane. This, with aeroplanes of usual form, is in the plane of symmetry of the aeroplane, and at a distance equal to about one-third of the width of the plane rearward from its front edge. With this arrangement, the pressures on the steering plane are approximately balanced with respect to the center of movement, regardless of the angular position of the plane. When the angle of incidence of an aeroplane is changed within the limits suitable for flight, its center of effort shifts slightly in a fore and aft direction. The fulcrum arms 21 are spaced away from the universal joint sufficiently far in a fore and aft direction to insure that the center of effort will at all times lie between them, and the length of the arms 21, and their distance from the center of universal movement are so proportioned that the plane will normally return to its normal position for horizontal flight, but will require the expenditure of but a small amount of power to tilt it. Practically all of the lateral pull of the steering plane when tilted laterally is transmitted to the frame of the machine through the universal joint and the strut 15, whereas, the only power which the operator must exert in order to keep the plane tilted is enough to tilt the plane against the downward pull of the stays 18 and 19 upon the fulcrum arms when said arms are displaced from a vertical position by the tilting of the plane. This is usually only a comparatively small component of the upward pull of the steering plane upon the stays 18. The lower plane 1 and the steering plane 3 also have inherent lateral stability due to their upwardly diverging dihedral form, as is well known. All of these features combined tend to promote normal stability, which will insure that the machine will advance straight ahead in an upright position in case of accident to the operator, or the controlling mechanism, or in case the operator lets go of the handle-bars, regardless of whether the machine is driven by its motor or merely gliding.

It is well known that in bi-planes, the

lower plane has the effect of deflecting the air above it to such an extent as to greatly reduce the lifting efficiency of the upper plane. This fault is further accentuated by the resistance which is offered by the structure of the machine. In order to counteract this fault, the body frame is so constructed that the upper plane will always have a greater angle of incidence than the lower plane, and the upper plane is extended laterally beyond the ends of the lower plane so as to reach air which is undisturbed by the lower plane.

From Figs. 15 and 16, it will be noticed that the fore and aft elements of the main planes are so disposed that each will have a greater angle of incidence at its middle part than at its ends. This has the important advantage of reducing the effective area of the main planes as the machine increases its speed, and therefore makes horizontal flight possible with a large range of speed variation. As the speed increases, the angle of incidence of the main planes is reduced, and as the angle of incidence of the main planes is reduced, the end portions first of the lower plane and then of the upper plane move toward positions in which they have no angle of incidence, or a negative angle of incidence. With these planes shaped as shown, maximum lifting effect is always in the center, and does not shift rapidly from side to side with change of transverse level, as is the case with planes which have a straight transverse form with the same angle of incidence from end to end.

As the machine approaches the ground to alight, the operator tilts the steering plane 3 forward so as to reduce its angle of incidence, and thereby reduce its lifting effect until it assumes the attitude indicated in Fig. 2 with reference to the line C as the horizontal. Then the main planes 1 and 2 are at their maximum angle of incidence, which increases their head resistance and the rearward end of the spring skid 5 engages the ground, all tending to reduce the speed of advance of the machine. As the skid extends a considerable distance rearward of the center of gravity, the machine gradually tips forward as the lifting effect of the planes 1 and 2 is reduced by the reduction of speed. As the machine tilts forward, the wheels 9 engage the ground, and then after further reduction of speed and lifting effect of the planes, the wheels 9 yield and the machine continues to tip forward until it rests upon the three wheels in the attitude represented by Fig. 2, with reference to the line A, as the horizontal. The center of gravity will now be between the wheels, and the machine will rest in stable equilibrium.

The design of the machine is such that the center of buoyancy of the air cells in the aeroplane 1 will be in advance of the center of gravity, so that the machine will float in an upright position when supported on the water.

The balancing influence of the steering plane 3, aside from the stabilizing effect of the main planes, when the machine is tipped toward one side, will be more clearly understood from Fig. 21, if we assume that the machine is tipped toward one side, so that the vertical line through the center of gravity is represented by the line V in said figure. If, when the machine is tipped to this position, the plane 3 is turned to a horizontal position represented by the line 3, which is at right angles to the line V, the upward pressure on the steering plane will coact with the downward pull of gravity, and tend to turn the machine about an axis extending through the resultant center of effort of all of the planes in the direction of flight, and this corrective influence, as will be seen from Fig. 21, is mainly proportional to the distance of the steering plane from such axis. The fact that the steering plane is of dihedral form, and is secured to the frame of the machine at a point below its center of effort, will cause it to tend to assume a horizontal position at all times. This stabilizing effect of the plane is therefore automatic, and does not require thought on the part of the operator.

Although but one specific embodiment of this invention is herein shown, it will be understood that numerous details of the construction shown may be altered or omitted without departing from the spirit of this invention, as defined by the following claims.

I claim:—

1. In a flying machine, the combination of a plurality of aeroplanes located one behind and above another in the normal attitude of the machine for horizontal flight, a frame connecting them, the rearward one of said aeroplanes being mounted in said frame to rotate about a vertical axis and being tiltable in both fore and aft and lateral directions about a center lying substantially in said axis, and means acting between said rearward aeroplane and said frame and adapted through the pressure on said steering aeroplane to cause the same to tend to assume its normal position, and thereby tending to urge the machine toward its normal attitude for horizontal flight.

2. In a flying machine, the combination of a plurality of aeroplanes located one behind another, a frame connecting them, said frame comprising an upright extending through the rearward one of said aeroplanes, a universal joint connecting said upright with said rearward aeroplane and vertically movable along said upright, means for tilting said rearward aeroplane

to various angular positions with respect to said upright, and means connecting said rearward aeroplane to said frame and adapted through the air pressure on said rearward aeroplane to urge it to a certain predetermined position with respect to said frame.

3. In a flying machine, the combination of a plurality of aeroplanes located one behind another, said frame comprising an upright extending through the rearward one of said aeroplanes, a universal joint connecting said upright with said rearward aeroplane and vertically movable along said upright, means for tilting said rearward aeroplane to various angular positions with respect to said upright, means for rotating said rearward aeroplane about the axis of said upright, and means connecting said rearward aeroplane to said frame and adapted through the air pressure on said rearward aeroplane to urge it to a certain predetermined position with respect to said frame.

4. In a flying machine, the combination of a plurality of aeroplanes located one behind another and one being relatively movable for steering, a frame connecting them, said frame comprising an upright extending through said steering aeroplane, a universal joint connecting said upright with said steering aeroplane and vertically movable along said upright, stays for limiting the upward movement of said steering aeroplane on said upright and secured to said steering aeroplane at points below the center of said universal joint and respectively in front of and behind said upright, whereby said steering aeroplane will normally assume a position of equilibrium symmetrical with respect to a vertical plane extending through said universal joint in the direction of flight, and means independent of the pressure on said steering aeroplane and yieldingly supporting the weight thereof.

5. In a flying machine, the combination of a frame, a plurality of aeroplanes coacting in the support of the machine, one of said aeroplanes being mounted to have universal movement about a center located inward of its marginal edges and being adapted through such movement to steer the machine, and means connecting said movable aeroplane to said frame and adapted through the pressure of the air on said movable aeroplane to normally urge said movable aeroplane to a certain definite position with respect to the frame and thereby tending to urge said machine toward its normal attitude for horizontal flight.

6. In a flying machine, the combination of a plurality of aeroplanes located one behind another and one being relatively movable for steering, a frame connecting them, said frame comprising an upright extending through said steering aeroplane, a universal joint connecting said upright with said steering aeroplane and vertically movable along said upright, stays for limiting the upward movement of said steering aeroplane on said upright and secured to said steering aeroplane at points below the center of said universal joint and respectively in front of and behind said upright, whereby said steering aeroplane will normally assume a position of equilibrium symmetrical with respect to a vertical plane extending through said universal joint in the direction of flight.

7. In a flying machine, the combination of a plurality of aeroplanes located one behind another and one being relatively movable for steering, a frame connecting them, said frame comprising an upright extending through said steering aeroplane, a universal joint connecting said upright with said aeroplane and vertically movable along said upright, stays for limiting the upward movement of said steering aeroplane on said upright and secured to said steering aeroplane at points below the center of said universal joint and respectively in front of and behind said upright, whereby said steering aeroplane will normally assume a position of equilibrium symmetrical with respect to a vertical plane extending through said universal joint in the direction of flight, and means independent of the pressure on said steering aeroplane for normally urging it upward to maintain a tension on said stays.

8. In a flying machine, the combination of a main aeroplane structure, a body frame connected in rigid relation to said main aeroplane structure, a steering aeroplane coacting with said main aeroplane structure in the support of the body frame and mounted to have universal movement with respect to said main aeroplane structure and being thereby adapted to steer the machine both horizontally and vertically and to maintain lateral and longitudinal balance, said steering aeroplane being mounted so that its center of universal movement may be capable of vertical movement in said frame, a pair of tension stays secured to said steering aeroplane at points within the plane of symmetry thereof and respectively in front of and behind said center of universal movement and also below and out of alinement therewith, whereby the air pressure upon said steering aeroplane will normally urge it to a certain initial disposition with respect to said frame.

9. In a flying machine, the combination of a supporting frame, a steering plane mounted to have universal movement about a center located substantially in the fore and aft vertical plane of symmetry of said steering plane, guiding means connected to

said frame and adapted to permit said plane to move vertically to a limited extent at said center of universal movement, and a pair of fulcrum arms on said plane, means connecting said fulcrum arms to said supporting frame, said fulcrum arms being located at opposite sides of the center of universal movement of said steering plane and in the fore and aft line of symmetry thereof, and being located below said center so that the air pressure on said steering plane will normally hold it in a substantially horizontal position.

10. In a flying machine, the combination of a supporting frame, a steering aeroplane symmetrically shaped with respect to a fore and aft vertical plane of symmetry and mounted to have universal movement about a center located substantially in the fore and aft vertical plane of symmetry, means connecting said steering aeroplane with said supporting frame, being connected to said steering aeroplane at a point below the center of effort thereof and in said fore and aft plane of symmetry, whereby the air pressure on said steering aeroplane will normally urge it to assume a certain normal disposition with respect to said frame.

11. In a flying machine, the combination of a main aeroplane structure, a steering aeroplane symmetrically shaped with respect to a vertical plane parallel with the normal direction of flight, a vertically disposed member connected with said main aeroplane structure, a ball slidably mounted on said member, a socket mounted on said steering aeroplane and engaging said ball to provide universal movement for said steering aeroplane, a pair of stays for limiting the upward movement of said steering aeroplane on said member and secured to said steering aeroplane at points located below the center of said ball and respectively in front of and behind said ball and in the fore and aft plane of symmetry of the steering aeroplane, whereby said steering aeroplane will be normally urged into such position that its plane of symmetry will be coincident with said upright member.

12. In a flying machine, the combination of a main supporting aeroplane structure, a steering aeroplane connected therewith and coacting therewith in the support of the machine, means providing for universal movement of said steering aeroplane with respect to said main aeroplane structure, a steering member mounted to rotate about a longitudinal axis and to oscillate about a transverse axis, four cables connected to said member at points symmetrically arranged with respect to the center of oscillation of said member and having their opposite ends connected to said steering aeroplane at points symmetrically arranged with respect to the center of universal movement thereof, whereby the oscillation or rotation of said member will cause corresponding movements of said steering aeroplane, a relatively movable part carried by said member, and a pair of cables connecting said part with said steering aeroplane at points symmetrically located with respect to the center of universal movement thereof and adapted through the movement of said part relatively to said member to tilt said steering aeroplane laterally on its center of universal movement.

13. In a flying machine, the combination of a pair of main supporting aeroplanes located one above the other and symmetrical with respect to a vertical plane parallel with the line of flight, said aeroplanes being of opposite dihedral form with respect to each other and one of said aeroplanes having its lateral end portions disposed at dihedral angles different from its middle portions, and a horizontally disposed steering aeroplane spaced rearwardly away from said main supporting aeroplanes along the line of flight and so mounted with respect to said main aeroplanes that during normal flight its center of effort will be above a line through the center of effort of said main aeroplanes and parallel with the direction of normal forward flight, said steering aeroplane being rotatable about a vertically disposed axis, said steering aeroplane having its lateral portions disposed in upwardly diverging dihedral relation to each other, and means adapted through the pressure of the air on said steering aeroplane to normally urge said steering aeroplane to a certain predetermined position with respect to said frame.

14. In a flying machine, the combination with an aeroplane structure, of a steering plane mounted thereon for relative angular movement, and a pair of stays spaced from the axis of such angular movement connecting said steering plane with said structure and adapted through the pressure of the air on said steering plane to normally urge it to a certain definite normal position for horizontal flight, said stays being located respectively fore and aft of the center of universal movement and being relatively adjustable to vary the normal fore and aft disposition of said steering plane.

Signed at Chicago this 2nd day of July 1910.

JAMES S. STEPHENS.

Witnesses:
EUGENE A. RUMMLER,
MARY M. DILLMAN.