Feb. 15, 1938. C. H. ZIMMERMAN 2,108,093

AIRCRAFT

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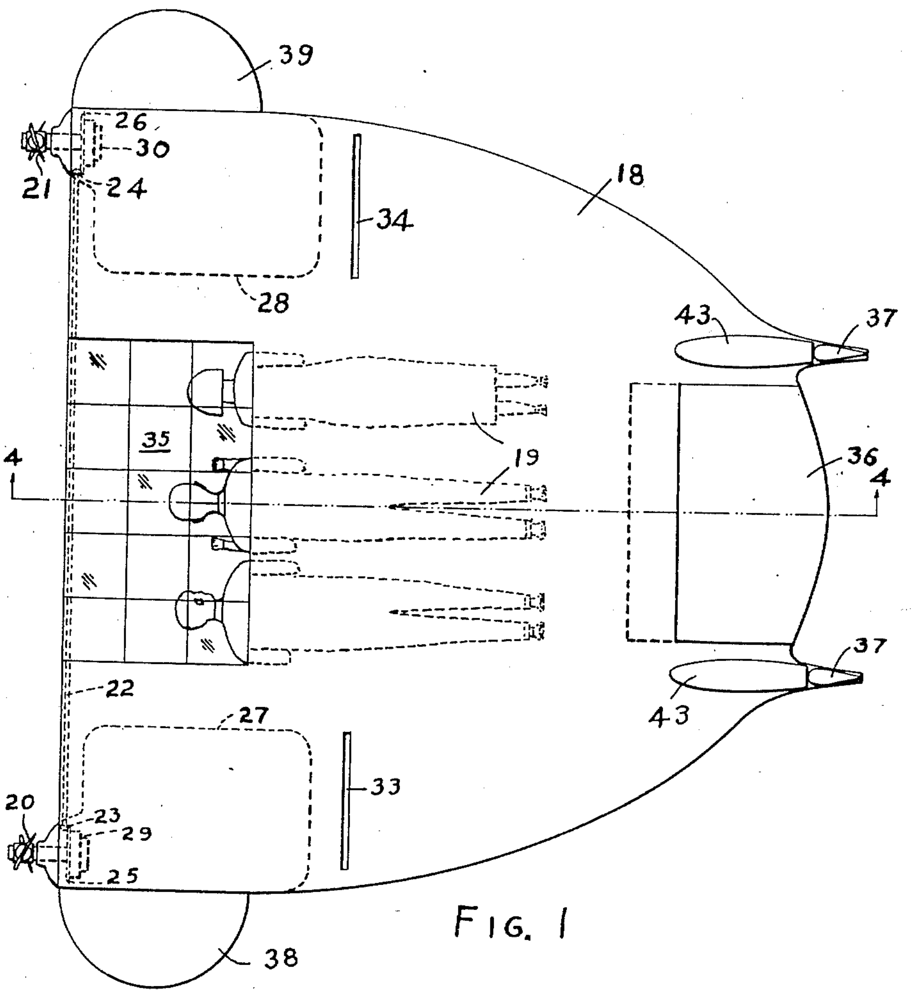

FIG. 1

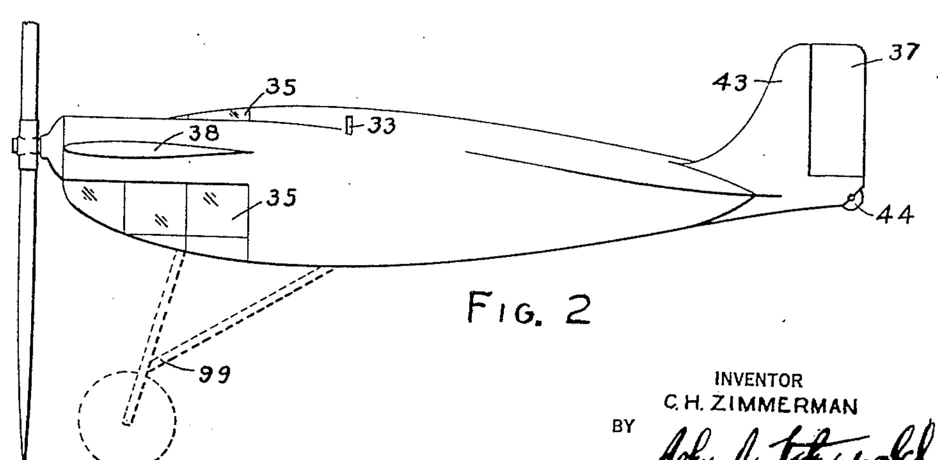

FIG. 2

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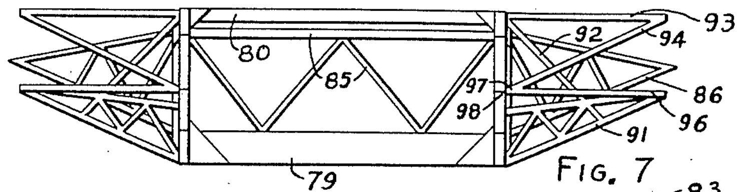

FIG. 7

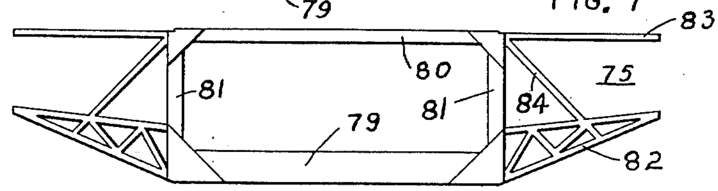

FIG. 6

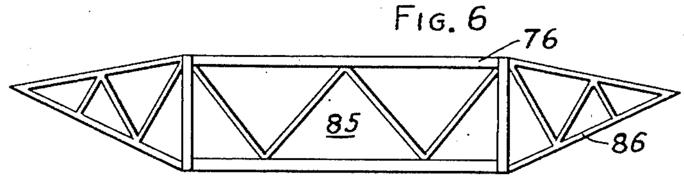

FIG. 5

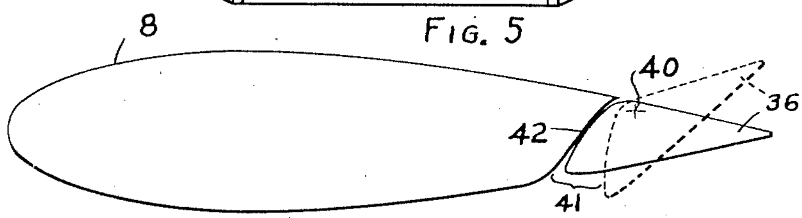

FIG. 4

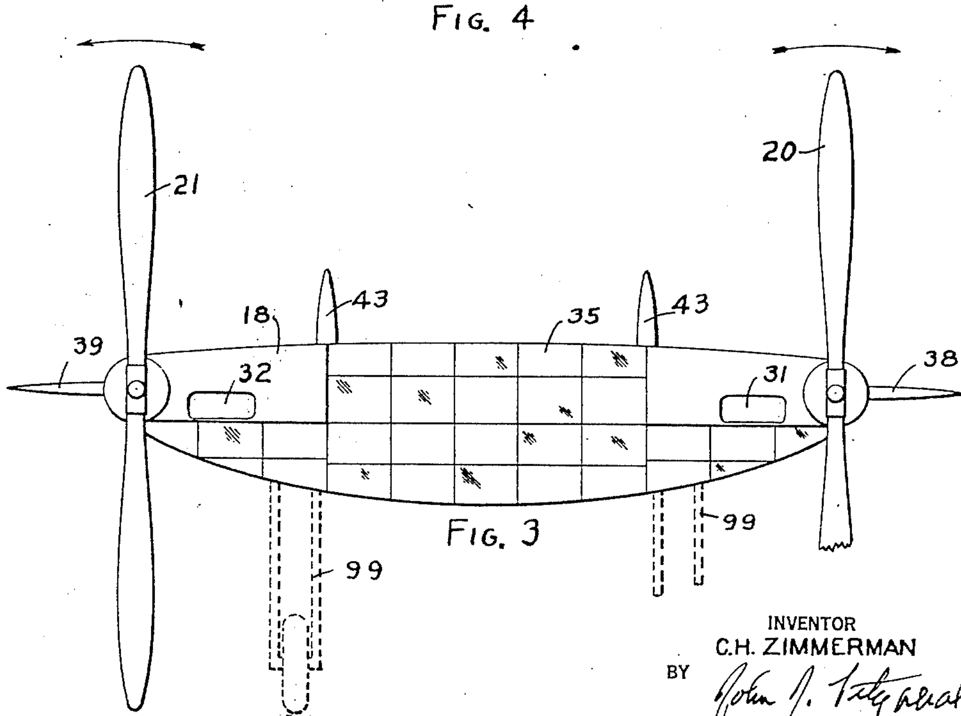

FIG. 3

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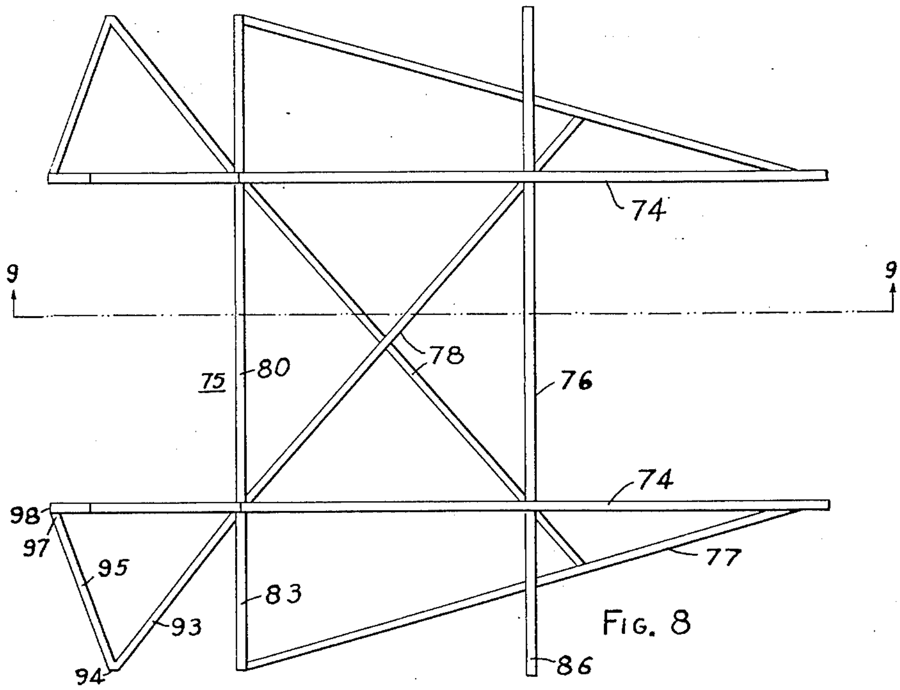

FIG. 8

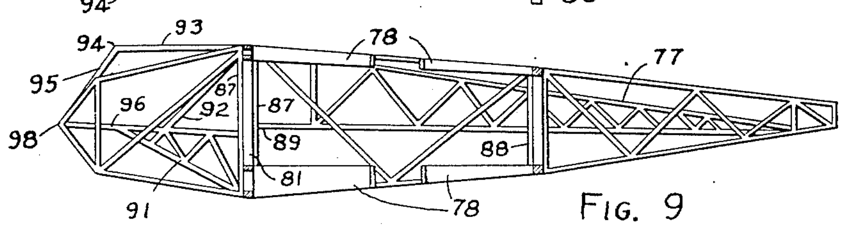

FIG. 9

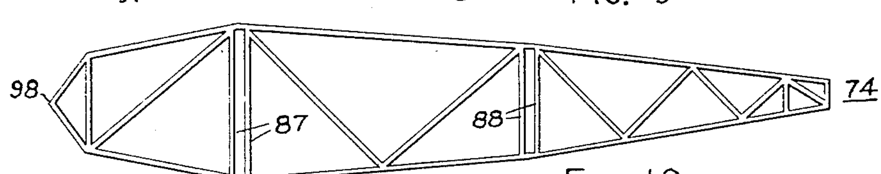

FIG. 10

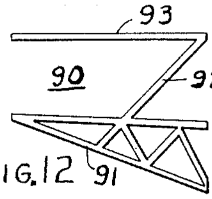

FIG. 12

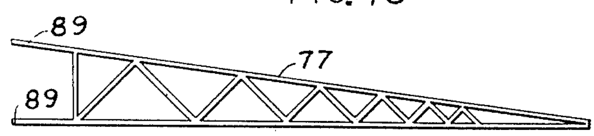

FIG. 11

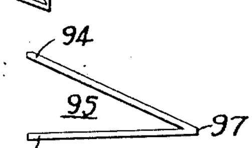

FIG. 13

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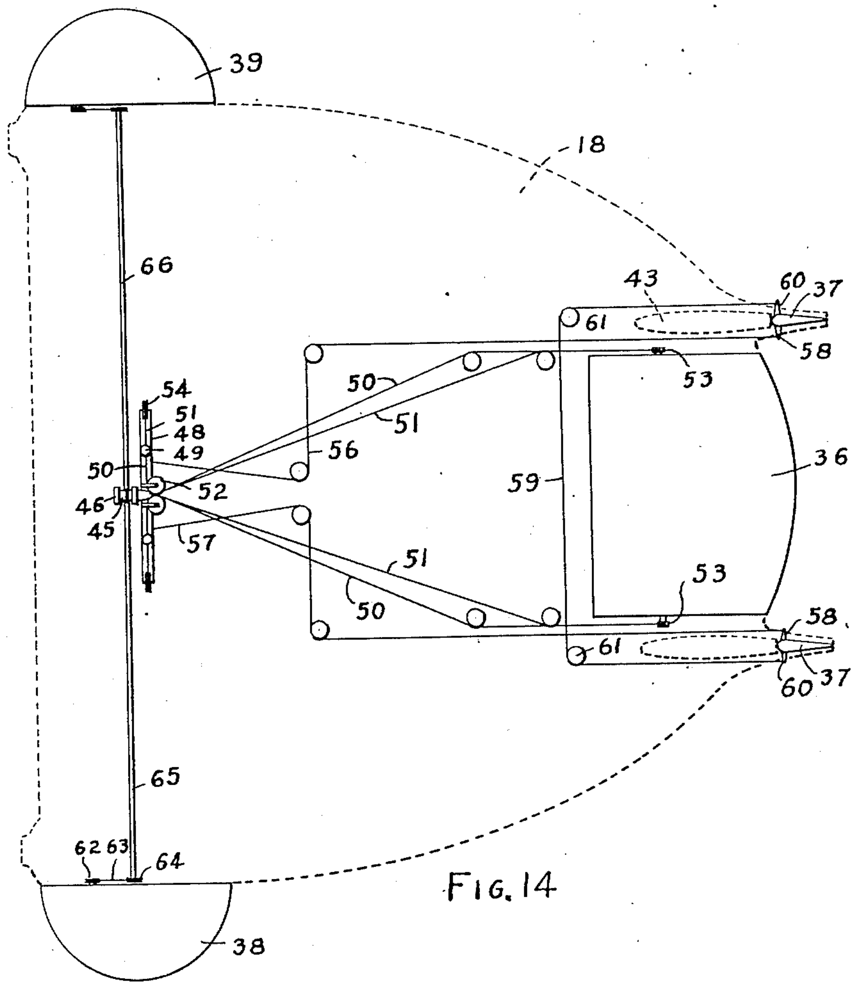

FIG. 14

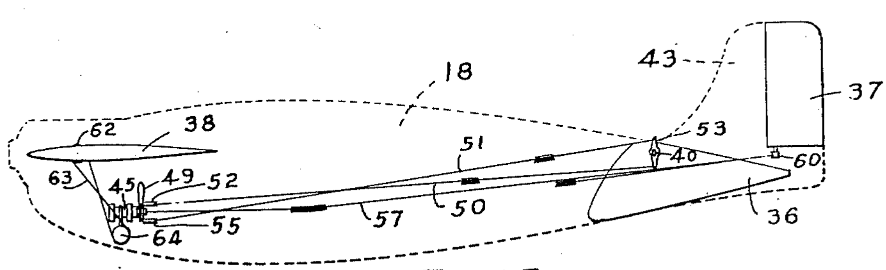

FIG. 15

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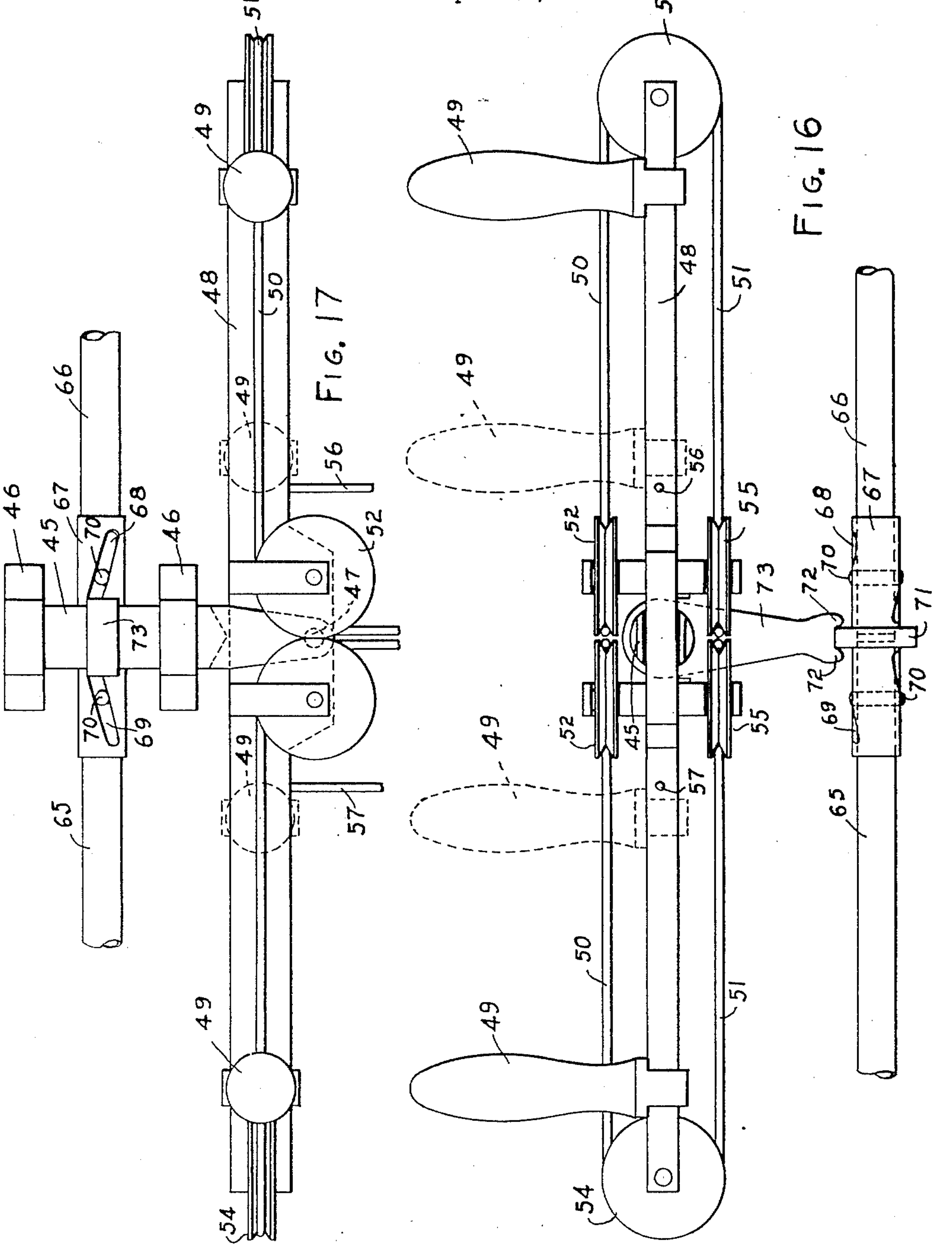

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Patented Feb. 15, 1938

2,108,093

UNITED STATES PATENT OFFICE

2,108,093

AIRCRAFT

Charles H. Zimmerman, Hampton, Va.

Application April 30, 1935, Serial No. 18,980

11 Claims. (Cl. 244—36)

(Granted under the act of March 3, 1883, as amended April 30, 1928; 370 O. G. 757)

This invention relates to a novel type of aircraft wherein the primary structure serves the three-fold purpose of fuselage, wing structure and engine mount.

Among the objects of this invention are:

To provide an aircraft capable of high speed in normal flight, of ascending and descending vertically, and of hovering without substantial horizontal motion;

To utilize the energy heretofore wasted in the twist of the slip-stream;

To reduce drag by neutralizing wing tip vortices;

To dispose and operate the propellers at or near the wing tips to increase the effective span;

To provide an aircraft having improved dynamic stability at low speed; and,

To provide an aircraft whereof the controlling surfaces are effective even at low speeds.

In the drawings:

Fig. 1 is a top plan view of the present invention;

Fig. 2 is a side elevation thereof;

Fig. 3 is a front elevation thereof with the retractable landing gear shown by dotted lines, in landing position;

Fig. 4 is a schematic side elevation showing the relation of the rear vertical control surface to the body of the craft;

Fig. 5 is a side elevation of the rear spar;

Fig. 6 is a like showing of the front spar;

Fig. 7 is a front elevation of the structural framework;

Fig. 8 is a top plan view of the structural framework;

Fig. 9 is a section through Fig. 8 on the line 9—9, looking in the direction of the arrows;

Fig. 10 is a side elevation of one of the main longitudinals;

Fig. 11 is a side elevation of one of the diagonal thrust braces;

Figs. 12 and 13 are side elevations of members forming the engine mount;

Figs. 14 and 15 are, respectively, a diagrammatic top plan view and a diagrammatic side elevation of the mechanism for operating the control surfaces;

Figs. 16 and 17 are, respectively, a side elevation and a top plan view of the mechanism for manipulating the control operating mechanism.

The present invention approximates the ultimate ideal for high speed aircraft, which is a stream-line body enclosing the load and the power plants with other accessories, and flattened so that its cross section is elliptical rather than round, efficiently to provide lift at high speeds.

Another feature of novelty which increases the over-all efficiency above that of other aircraft of the same span loading at the same speed is the location of the propellers at the wing tips and their rotation in such directions that most of the energy which would otherwise be lost in twist of the slip-stream is returned to the machine in the form of diminished induced drag.

Essentially, the present invention consists of a stream-line body, of which fore-and-aft sections are airfoil profiles and transverse sections are approximately ellipses, housing the load and accessories and mounting the control surfaces and engines; two engines of light weight per horsepower; and controllable pitch propellers mounted at the wing tips and rotating so that the blade tips move downwardly when farthest from the plane of symmetry of the machine. Two engines are used so that torque and gyroscopic couples will be neutralized, to provide structural and aerodynamic efficiency and to make possible the continuation of flight on one engine in case of the failure of the other.

While the maximum aerodynamic efficiency is realized by the sectional contour shown as above mentioned, it is to be understood that the enclosure for the pilot and passengers may be made deeper and be suitably faired into the adjacent part of the surface of the craft.

The stream-lined body of the craft forms a low-aspect-ratio airfoil. The shape chosen is such as to create a minimum of profile drag and has sufficient span to keep the induced drag to a small value at cruising speeds.

As is shown in Figs. 1, 2 and 3, the entire surface of the illustrated embodiment of the present invention is stream-lined in all dimensions. The substantially elliptical cross-sectional shape provides an effective dihedral angle on the lower surface, and the fore-and-aft contour is such as to secure a smooth, substantially undisturbed flow of air over the craft. The most efficient stream-lining requires that the depth of the body 18, in smaller machines, be such that the pilot and passengers, if any, occupy a prone position as indicated at 19 in Fig. 1. This position is not objectionable and is by far the most comfortable in case of air-sickness. As above stated, the depth may be made greater to permit the pilot to sit as in conventional aircraft, but except for machines of large size this involves departures from the almost perfect stream-lining attained in the craft as shown.

The propellers 20 and 21 are mounted at the extreme tips of the entering edge of the craft and rotate in such directions that the tips of the blades move downwardly when farthest from the plane of symmetry. It is apparent that the described positions and directions of rotation of the propellers result in an increase of the effective span of the structure, since the upwardly acting component of reaction to the downwardly moving propeller blade beyond the wing tip is transmitted to the craft as lift. In addition, the energy normally wasted in the twist of the slip-stream is to a great extent recovered in that it acts upwardly upon the lower surface of the craft and thereby increases the lift, and on the upper surface thereof it sweeps outwardly toward the lateral edge and so prevents formation of wing-tip vortices and eliminates the very considerable induced drag due to such vortices.

The propellers are of the controllable-pitch type so that they may be given a low pitch when taking off or hovering and a higher pitch for high speed, substantially horizontal flight. The propellers 20 and 21 are constrained to rotate at the same speed by means of shaft 22 which has at its ends beveled pinions 23 and 24 meshed with beveled gears 25 and 26 which have a driving connection with the respective propeller shaft. The engines 27 and 28 are connected to the propellers by means of conventional reduction gearing and clutches indicated at 29 and 30 whereby, if one engine stops it may be disconnected from its propeller and the two propellers will be driven by the other engine at sufficient speed to enable the pilot to select a landing place and bring the machine down safely. Other advantages are derived from the described arrangement and operation of the propellers in that torque and gyroscopic couples are neutralized and there are no turning moments impressed upon the craft due to the rotation of one propeller at a speed different from that of the other. For example, if the craft rotates about its normal axis (i. e., the axis through the center of gravity perpendicular to the plane including both thrust lines) the propeller at the higher effective air speed would rotate more rapidly if the propellers were not connected together, and hence would tend to keep the thrust unchanged but when interconnected the propellers must turn at the same speed and the thrust differential tending to oppose the rotation about the normal axis will be much greater and hence will make for increased stability. Also, either motor may be stopped temporarily for minor repairs or readjustments during flight and then be restarted.

It will be observed that the axes of rotation of the propellers are always parallel to the longitudinal axis of the machine and hence are in the most favorable position for efficient flight whether normal or hovering. In this the present invention has a great advantage over craft of the helicopter type wherein the axis of rotation of the sustaining rotating members is at a large angle to the direction of motion in substantially horizontal flight. Because of this said large angle the air strikes the individual rotating blades at an angle which varies due to the blade rotation. This rapid variation of angle of the blade to the relative wind (a complete cycle of changes for each revolution of the sustaining member) results in large increase in drag and is therefore inherently inefficient.

It will further be observed that the propellers are so placed relative to the remainder of the craft that the propeller slip-streams are at all times directed over the lifting and control surfaces. With the fairly high loading of the propellers employed the slip-stream velocity will always be high, 60 to 100 miles per hour, so that the control surfaces will be very effective in hovering and low-speed flight. This is a definite advantage over helicopter types where a relatively low loading of the sustaining rotating member is used, for in the latter case the speed of the slip-stream or down-wash is low and cannot provide good control. The use of fairly heavily loaded propellers for lifting surfaces in hovering flight has an additional advantage over the use of comparatively lightly loaded sustaining rotating members as in the case of helicopters and other rotating wing devices in that gusts and changes in wind direction will produce much less violent changes in attitude or velocity of the craft.

The engines may be cooled by air drawn in through openings 31 and 32 (Fig. 3) and discharged through openings 33 and 34 (Fig. 1).

The enclosure for the forward part of the pilot and passenger compartment may be of transparent material, as indicated at 35, to permit freedom of vision in substantially all directions.

The control surfaces comprise an elevator 36, rudders 37 and, in cases where high maneuverability is desired, floating wing-tip ailerons 38 and 39. The elevator 36 is roughly a scalene triangle in a section parallel to the plane of symmetry of the craft, with the longer two sides forming continuations of the upper and lower surfaces of the aircraft body and the short side, which is somewhat convex, lying adjacent a correspondingly shaped surface 42 formed on the body adjacent thereto. It is mounted on a pivot 40, approximately in the angle between the upper surface and the leading edge surface of the elevator, or flap, whereby when the flap is tilted above the main surface a slot 41 is opened between the leading edge of the flap and the surface 42 on the body, which permits air to flow from the lower surface of the body up over the upper surface of the flap. This flow of air is very effective in controlling the craft in flight at high angles of attack and in hovering flight, as will be hereinafter set forth.

The rudders 37 are mounted immediately in the rear of fin surfaces 43, which are symmetrically disposed at the trailing edge of the craft. Tail wheels 44, or tail skids, are secured at the rear lower edge of the fins 43.

The floating wing-tip ailerons 38 and 39 will not necessarily be provided as the craft may be controlled perfectly by means of the elevator and rudders in conjunction with regulating the speed of the propellers, unless it is desired to make the machine highly maneuverable. These floating ailerons adjust themselves to lie always in the airstream without definite relative position with respect to the principal surfaces of the craft, but they may be tilted in opposite directions with respect to each other.

The controlling elements are moved by the mechanism shown in Figs. 14 to 17, which is especially designed for operation by a pilot in a prone position. A shaft 45 is mounted for rotation in suitable bearings 46 secured to the framework of the craft. One end of the shaft 45 is bifurcated and mounted therein on pivot 47 is a bar 48 which is thus movable in a plane parallel to the axis of shaft 45 and also rotatable about the said axis with the shaft. Slidably mounted on the bar 48 are handles 49 to which are connected the cables 50 and 51, the former passing over a sheave 52 and thence backwardly to one end of a horn 53 on the pivot of flap 36 and the latter passing around sheaves 54 and 55 to the other end of the horn 53. The connections of the cables 50 and 51 to the horns 53 are such that the handles are farthest separated from each other when the flap 36 is not tilted, that is, when it is in the position for high speed flight; the reason for this will presently appear. It is apparent that since both of the handles 49 are connected to operate the flap 36, vertical control of the machine may be exercised with one hand if desired.

Cables 56 and 57 are connected to the bar 48 on opposite sides of pivot 47 and extend backwardly to the horns 58 on the rudders 37, the two rudders being interconnected by a cable 59 that is attached to horns 60 on the rudders and passes over sheaves 61. The rotation of the bar 48 about pivot 47 tightens one of the cables 56 and 57 and slacks away on the other thereof, and this, through the interconnecting cable 59, simultaneously turns the rudder not directly acted upon by the lightened cable in the same direction as does the one so acted upon.

On the pivots of floating ailerons 38 and 39 are fixed sheaves 62 which have driving connection, as by means of belts 63, with sheaves 64 on shafts 65 and 66. It is to be understood that this manner of connecting the floating ailerons to the respective shafts 65 and 66 is illustrative merely and is not to be construed in a limiting sense. The inner ends of the shafts 65 and 66 are disposed in a sleeve 67 which is free to slide longitudinally on both of the shafts and which has in it oppositely disposed helical slots 68 and 69, the pins 70 fixed to the shafts 65 and 66 being slidable in the said slots. Midway between the ends of sleeve 67 is a radially extending circumferential rib 71 which rides between the limbs 72 of the bifurcated free end of a lever 73 that is fixed on shaft 45. When bar 48 is moved to rotate shaft 45, lever 73 will likewise be rotated and will shift the sleeve 67 longitudinally on shafts 65 and 66 which will, due to the coaction of pins 70 with slots 68 and 69, rotate the shafts 65 and 66 in opposite directions and consequently impart opposite angles of tilt to the floating ailerons 38 and 39. The connection between sleeve 67 and lever 73 leaves the shafts 65 and 66 free to rotate and permit the ailerons to float in the airstream but nevertheless is immediately effective to operate the ailerons when lever 73 is rotated by shaft 45.

Since the bar 48 is rotated about pivot 47 to actuate the rudders and is used to rotate shaft 45 to shift floating ailerons 38 and 39, it is apparent that a much more delicate and accurate control of the craft is obtained by having the handles 49 at the extremities of bar 48 in high speed flight.

The primary structure, as shown in Figs. 5 to 13, comprises main longitudinals 74, front spar 75, rear spar 76, diagonal thrust members 77 and main diagonal braces 78. Owing to the depth of the structure substantially all frame members, except the front spar and diagonal braces, are of plain truss construction which gives great strength to the framework. The front spar 75 has two box spar members 79 and 80 connected together by end members 81 to form an open rectangle which defines, in part, the enclosure for the pilot and passengers or load. Secured to each end of the said rectangle and lying substantially in the same plane, are a truss member 82 and upper member 83 and a diagonal tie 84 from the base of member 82 to substantially the midpoint of truss member 82, the members 82, 83 and 84 constituting a portion of the engine mount.

The rear spar 76 has a rectangular median portion 85 and triangular end portions 86, the portion 85 defining the rear end of the compartment.

The main longitudinals 74 are of trussed construction and of such outline as to make for complete fore-and-aft streamlining. The front and rear spars are passed between the spaced apart members 87 and 88, respectively, whereby they are held rigidly in position and become a unit with the longitudinals. The diagonals 78 may be either plain bars or angle bars as preferred. The diagonal thrust members 77 are substantially triangular and of trussed construction, the apex of each being connected to the adjacent longitudinal near the rear end of the longitudinal and the other ends 89 of the side members thereof are secured to the outer end of the members 83 and 82 which are carried by the front spar.

Connected to the front spar 75 and the main longitudinal 74 at their intersection is a member 90 so disposed as to be substantially a continuation of the diagonal 78. The member 90 consists of a triangular trussed portion 91 having connected to one side thereof the diagonal tie 92 and a bar 93 fixed at one end to the tie 92. Connected to the outer end of the bar 93 is the end 94 of one side of triangular member 95, the end 96 of the other side thereof being connected to the apex of triangular portion 91 of member 90 and the apex 97 of member 95 is connected to the main longitudinal 74 at the point 98. The member 90 also constitutes a portion of the engine mounting, the space between the portion 91 and 93 thereof being a continuation of the space between members 82 and 83 on the front spar. It will be seen from Fig. 8 that the primary structure is thoroughly braced and absolutely rigid in every direction, and although simple and light it possesses great strength.

The retractable landing gear 99 is connected to the primary structure at the intersection of the front spar 75, the main longitudinal 74, and the diagonal 78. It is thus disposed between the main loads made up of the engines and the load in the compartment for passengers, etc., and is at the point of greatest strength of the structure. The gear folds up into the space between the diagonal thrust member 77 and the main longitudinal 74.

In normal flight the movement of the craft vertically is controlled by the flap 36 which, at high speeds in rectilinear flight, will be almost neutral but with the trailing edge up slightly for balance.

As above set forth, the flap 36 is manipulated by means of the handles 39 and cables 50 and 51, the handles being substantially at the outer ends of bar 48 when the flap is neutral. It is unnecessary to make provision for tilting the flap downwardly through any large angle. When the flap 36 is raised the angle of attack is increased and the speed of the craft is reduced, the flow of air through the slot 41 over the upper surface of flap 36 having the effect of steadying the craft to make it more stable at low speed. When the flap 36 is near the upper limit of tilt the craft will ascend vertically, hover or descend vertically, depending upon the throttle setting of the engine and the pitch setting of the propeller blades.

Directional control of the craft is effected by means of the rudders 37 which are actuated when bar 48 is rotated about pivot 47. Normally, no control surface other than the rudders is required for turning the craft. In hovering flight, pulling back on the right-hand handle 49 causes the craft to move slowly to the right and vice versa.

When it is desired that the craft be highly maneuverable, the floating wing-tip ailerons 38 and 39 are used. The ailerons are normally free to set themselves parallel to the airstream and hence exert no moment upon the craft but when actuated through the bar 48 and lever 73, as above described, they cause the machine to execute unbanked turns and other maneuvers very rapidly. They also permit rolling without a change of course, the execution of side slips, and other normally unnecessary maneuvers.

Owing to the novelty of the hovering feature of this craft, it is desirable to set forth in some detail the method of operation in that type of flight. Longitudinal control in hovering is accomplished with the elevator surface, zero forward speed being accomplished by rotating the flap nearly to its extreme upward position. The machine can be made to travel slowly backward by setting the elevator to its upper limit. Any forward speed up to the top speed can be attained by setting the elevator at various intermediate positions between full up and neutral. Whether the machine rises, descends, or neither, depends on the throttle and propeller pitch setting at the particular elevator setting. For example, with the throttle and elevator set for slow cruising speed in level flight the machine will rise if the elevator is raised slightly but after further movement of the elevator will maintain level flight at considerably slower speed. Further upward movement of the elevator will cause the machine to descend with a still lower forward speed. It will be seen that in this manner the aeromobile can be landed by use of the elevator alone, it being necessary to throttle the motors only upon contact with the ground. Landing is effected by descending with the tail low, permitting the tail wheels or skids to touch the ground, and then throttling the engine so the front sinks down and the landing gear touches the ground.

Directional control in hovering flight may be accomplished with the rudders alone. If it is desired to counteract a sidewind or to move the aeromobile in a direction at right angles to the plane of symmetry the rudders are deflected so as to point the thrust lines in the direction of motion desired. The unbalanced thrust force will cause the machine to move sidewise but the velocity will be low because a condition of balance will soon be achieved between the control moment and the natural stability of the machine tending to return the plane of symmetry to a vertical position. When traveling sidewise in this manner the aeromobile will slowly turn about its longitudinal axis until it is headed in the direction toward which motion was started. Further motion in that direction can then be achieved by setting the flap to a lower angle.

Aeromobiles equipped with floating tip ailerons will be capable of rapid rotations about the longitudinal axis by reason of their operation in the high velocity slip-streams. This feature will give high maneuverability in hovering flight.

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

I claim:

1. An aircraft, comprising a structure affording an aerodynamic lifting surface, said structure having in it space for a pilot and for load, a controllable pitch propeller mounted at each tip of the leading edge of said structure in fixed relation to the longitudinal axis of the craft, a separate engine connected to each propeller, means positively connecting said propellers together to rotate at equal speeds and in such directions that the blades thereof move down when farthest from the plane of symmetry of the craft, a movable control element adapted to form, in effect, a portion of the upper and lower surfaces of said structure and also of the trailing edge thereof, the said element being mounted on a pivoted axis rearwardly of its foremost portion and adjacent its upper surface, whereby when the trailing edge of said element is raised a slot is opened to permit air to pass from the lower surface of said structure over the upper surface of the element, said slot having its greatest width on the lower surface of said structure a control element at each end of the first-mentioned element and extending substantially at right angles to the pivot axis of said first-mentioned element, and means to operate all said control elements, the center of gravity of said craft being fixed.

2. An aircraft, comprising a structure affording an aerodynamic lifting surface, said structure having in it space for a pilot and for load, a controllable pitch propeller mounted at each tip of the leading edge of said structure in fixed relation to the longitudinal axis of the craft, a separate engine connected to each propeller to rotate said propeller in such directions that the blades thereof move down when farthest from the plane of symmetry of the craft, a movable control element adapted to form, in effect, a portion of the upper and lower surfaces of said structure and also of the trailing edge thereof, the said element being mounted on a pivoted axis rearwardly of its foremost portion and adjacent its upper surface, whereby when the trailing edge of said element is raised a slot is opened to permit air to pass from the lower surface of said structure over the upper surface of the element, said slot having its greatest width on the lower surface of said structure a control element at each end of the first-mentioned element and extending substantially at right angles to the pivot axis of said first-mentioned element, and means to operate all said control elements, the center of gravity of said craft being fixed.

3. An aircraft, comprising a structure affording an aerodynamic lifting surface, said structure having in it space for a pilot and for load, a propeller mounted at each tip of the leading edge of said structure in fixed relation to the longitudinal axis of the craft, a separate engine connected to each propeller, means positively connecting said propellers together to rotate at equal speeds and in such directions that the blades thereof move down when farthest from the plane of symmetry of the craft, a movable control element adapted to form, in effect, a portion of the upper and lower

surfaces of said structure and also of the trailing edge thereof, the said element being mounted on a pivoted axis rearwardly of its foremost portion and adjacent its upper surface, whereby when the trailing edge of said element is raised a slot is opened to permit air to pass from the lower surface of said structure over the upper surface of the element, said slot having its greatest width on the lower surface of said structure a control element at each end of the first-mentioned element and extending substantially at right angles to the pivot axis of said first-mentioned element, and means to operate said control element, the center of gravity of said craft being fixed.

4. An aircraft, comprising a structure affording an aerodynamic lifting surface, said structure having in it space for a pilot and for load, a propeller mounted at each tip of the leading edge of said structure in fixed relation to the longitudinal axis of the craft, a separate engine connected to each propeller to rotate said propeller in such direction that the blades thereof move down when farthest from the plane of symmetry of the craft, a movable control element adapted to form, in effect, a portion of the upper and lower surfaces of said structure and also of the trailing edge thereof, the said element being mounted on a pivoted axis rearwardly of its foremost portion and adjacent its upper surface, whereby when the trailing edge of said element is raised a slot is opened to permit air to pass from the lower surface of said structure over the upper surface of the element, said slot having its greatest width on the lower surface of said structure a control element at each end of the first-mentioned element and extending substantially at right angles to the pivot axis of said first-mentioned element, and means to operate all said control elements, the center of gravity of said craft being fixed.

5. An aircraft, comprising a structure affording an aerodynamic lifting surface, said structure having in it space for a pilot and for load, a controllable-pitch propeller mounted at each tip of the leading edge of said structure in fixed relation to the longitudinal axis of the craft, a separate engine connected to each propeller, means positively connecting said propellers together to rotate at equal speeds and in such directions that the blades thereof move down when farthest from the plane of symmetry of the craft, a floating aileron mounted on each side of said structure adjacent the leading edge thereof in the slipstream of the adjacent propeller, means to operate said ailerons, and other means for exercising directional and longitudinal control of said craft, the center of gravity of said craft being fixed.

6. An aircraft, comprising a low aspect ratio body structure of substantially elliptical curvature on its lower surface in all cross sections at right angles to the longitudinal axis thereof with the major axis of the ellipse horizontal to form an effective dihedral angle on said lower surface; and streamlined parallel to said axis, a propeller mounted at each lateral extremity of the leading edge of said body, means so to drive said propellers that the blades of each move downwardly when farthest from the plane of symmetry of the body, and control surfaces disposed at the trailing edge of said structure to be acted upon continuously by the propeller slip stream over said body.

7. An aircraft, comprising a body structure having substantially equal length and breadth, said body having a substantially elliptical curvature on its lower surface in cross section at right angles to the plane of symmetry thereof with the major axis of the ellipse horizontal to form an effective dihedral angle on said lower surface and being streamlined parallel to said axis, a propeller mounted at each lateral extremity of the leading edges of said body, means so to drive said propellers that the blades of each move downwardly when farthest from the plane of symmetry of the body, and control surfaces disposed to be acted upon by the propeller slip stream over said body comprising a flap adapted to form a substantially continuous portion of said body, mounted to open a slot that is widest on the lower surface when the trailing edge of said flap is raised.

8. An aircraft, comprising a low aspect ratio body structure of substantially elliptical curvature on its lower surface in all cross sections at right angles to the longitudinal axis thereof with the major axis of the ellipse horizontal and streamlined parallel to said axis, a propeller mounted at each lateral extremity of the leading edge of said body, means so to drive said propellers that the blades of each move downwardly when farthest from the plane of symmetry of the body and a movable control element adapted to form, in effect, a substantially continuous portion of the upper and lower surfaces of said body and of the trailing edge thereof when not displaced, the said element being mounted on a pivoted axis rearwardly of its foremost portion and adjacent its upper surface, whereby when the trailing edge of said element is raised a slot is opened to permit air to pass from the lower surface of said body to the upper surface thereof over the upper surface of said element, said slot having its greatest width on the lower surface of said body.

9. An aircraft, comprising a structure affording an aerodynamic lifting surface, and a movable control element adapted to constitute, in effect, a portion of the upper and lower surfaces of said structure and also of the trailing edge thereof, said element being substantially in the form of a scalene triangle in fore-and-aft cross section, with the shortest side at the leading edge and somewhat convex, the portion of the surface on said structure immediately adjacent said shortest side being somewhat concave and faired into said lower surface, a pivotal mounting for said element disposed substantially in the angle between said shortest side and the side forming the upper surface of said element, whereby when the trailing edge of said element is raised a slot is opened through which air flows to pass to the upper surface of said control element, said slot having its greatest width on the lower surface of said structure, and means to rotate said element on its pivotal mounting, the cross section of said slot transverse to the length of the slot being of a shape substantially to prevent turbulence in the slot.

10. A spar unit for an aircraft lifting structure, comprising a main portion substantially in the form of a rectangle, a cantilever member forming an extension of one side thereof at each terminus of said side, substantially triangular trussed members secured to said portions to extend respectively parallel to said cantilever members in spaced relation thereto, and ties, each secured at one end to a cantilever member adjacent to the fixed end of the cantilever member, and at the other end to the adjacent one of said trussed members at a point intermediate the ends of such trussed member, said cantilever member

and the adjacent said triangular trussed member at each end of the spar cooperating as means for mounting an engine.

11. A spar unit for an aircraft lifting structure comprising a main portion having spaced apart members constituting a frame having a free opening elongated parallel to the span, said free opening being of an area substantially equal to that of said major portion, a cantilever member forming an extension of one major dimension of said portion at each terminus of said major dimension, substantially triangular trussed members secured to said main portion in spaced relation to the respectively adjacent cantilever member and parallel to said adjacent cantilever member, and ties, each secured at one end to a cantilever member adjacent to the fixed end of the cantilever member and at the other end to the adjacent one of said trussed members at a point intermediate the ends of such trussed member, each said cantilever member and the adjacent said triangular trussed member cooperating as means for mounting an engine.

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