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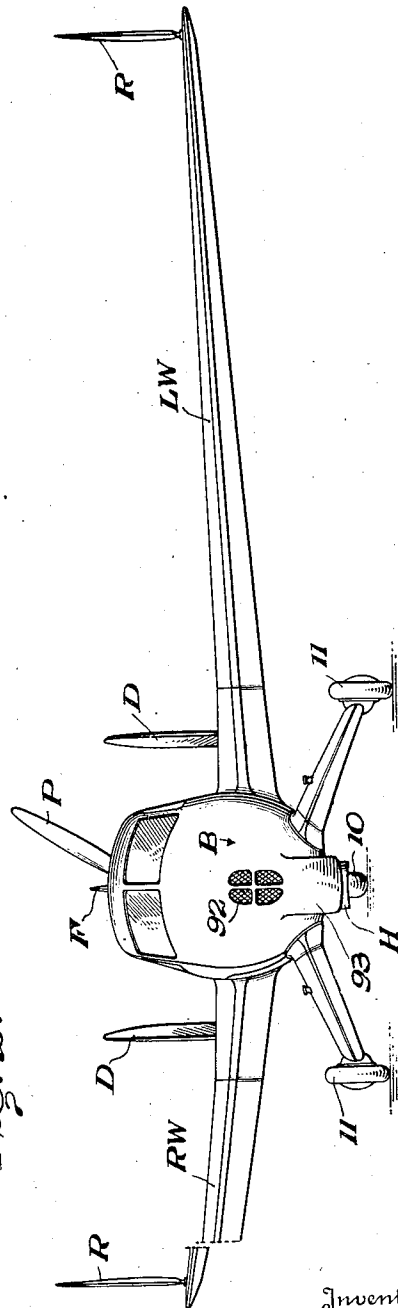
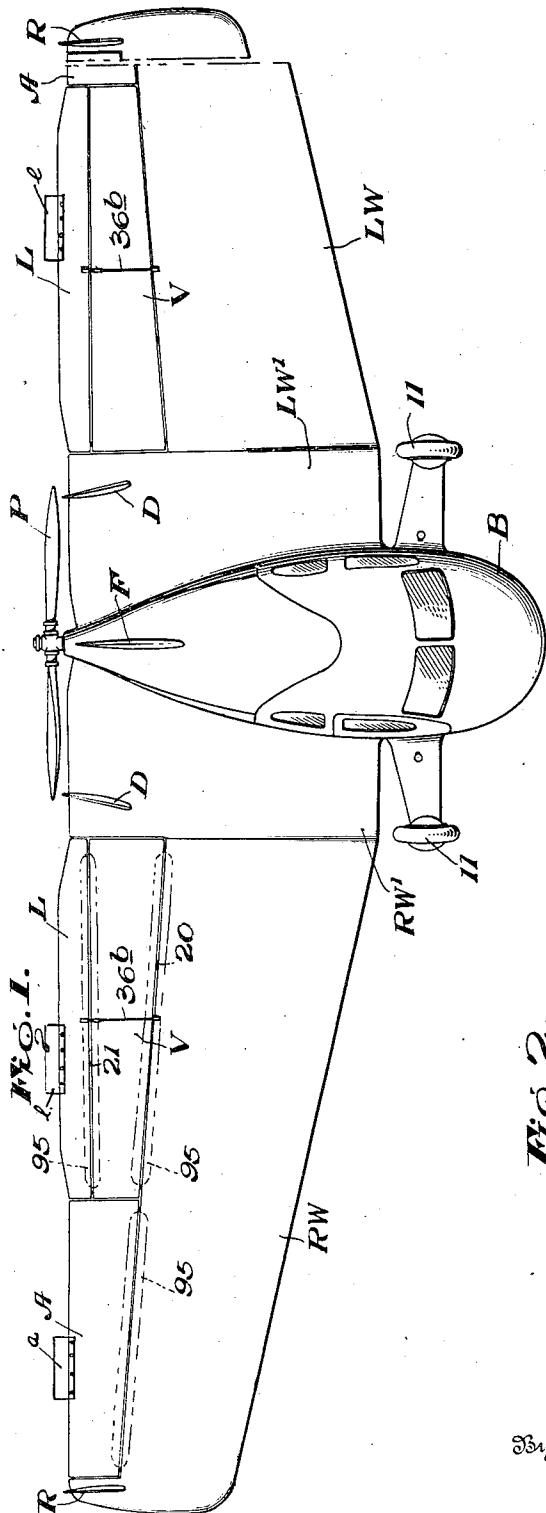
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2,390,939

AIRPLANE

Filed Aug. 13, 1938

7 Sheets-Sheet 1



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AIRPLANE

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7 Sheets-Sheet 2

Fig. 3.

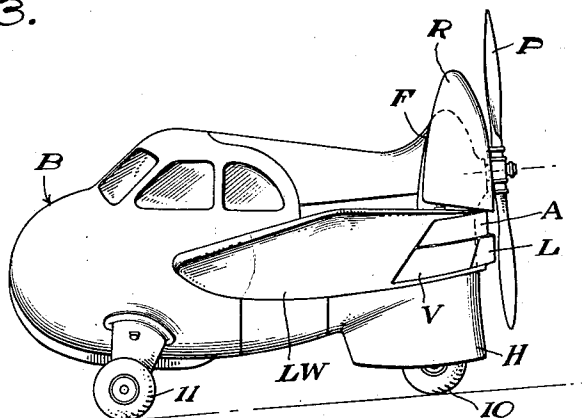


Fig. 4.

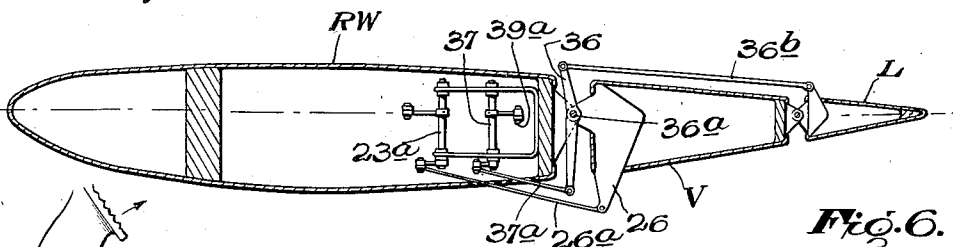


Fig. 5.

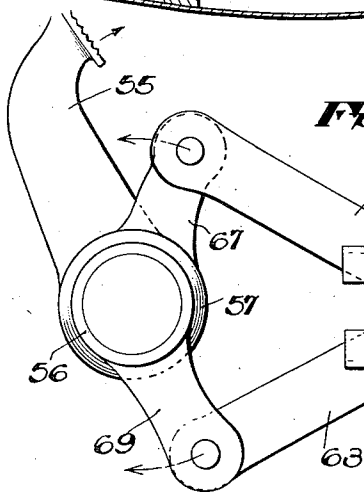
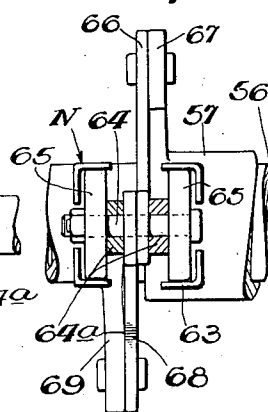


Fig. 6.



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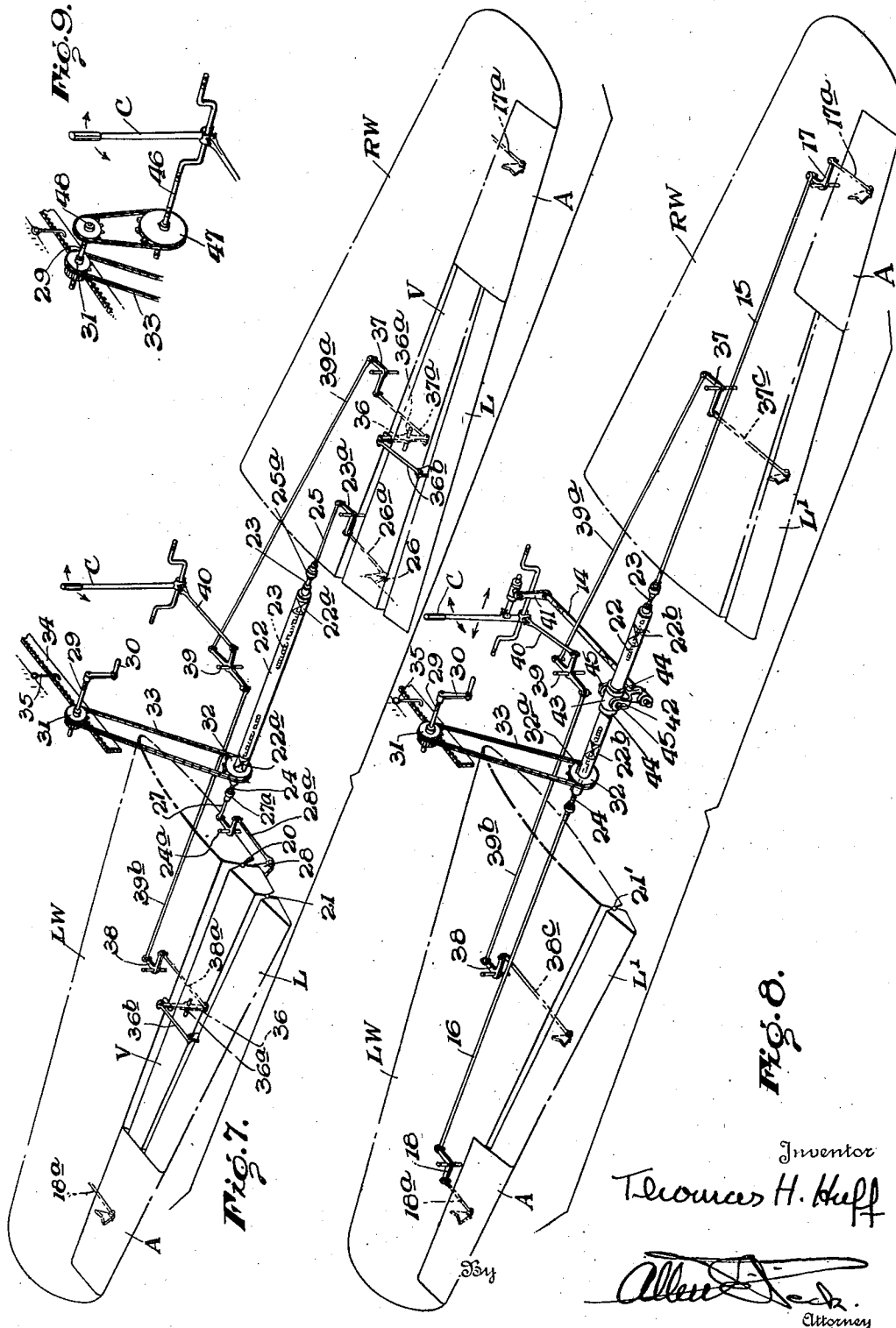
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AIRPLANE

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7 Sheets-Sheet 3



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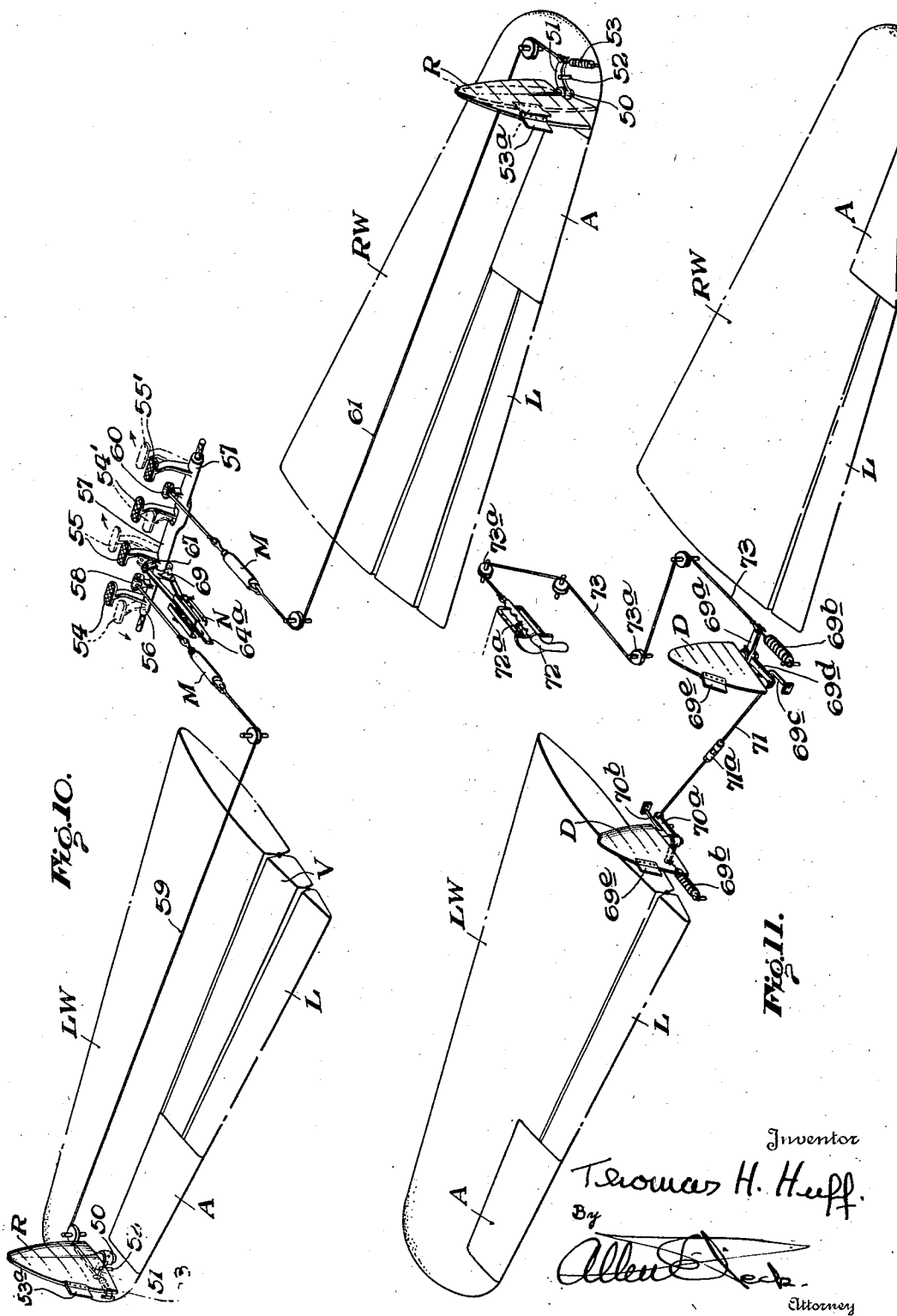
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7 Sheets-Sheet 4



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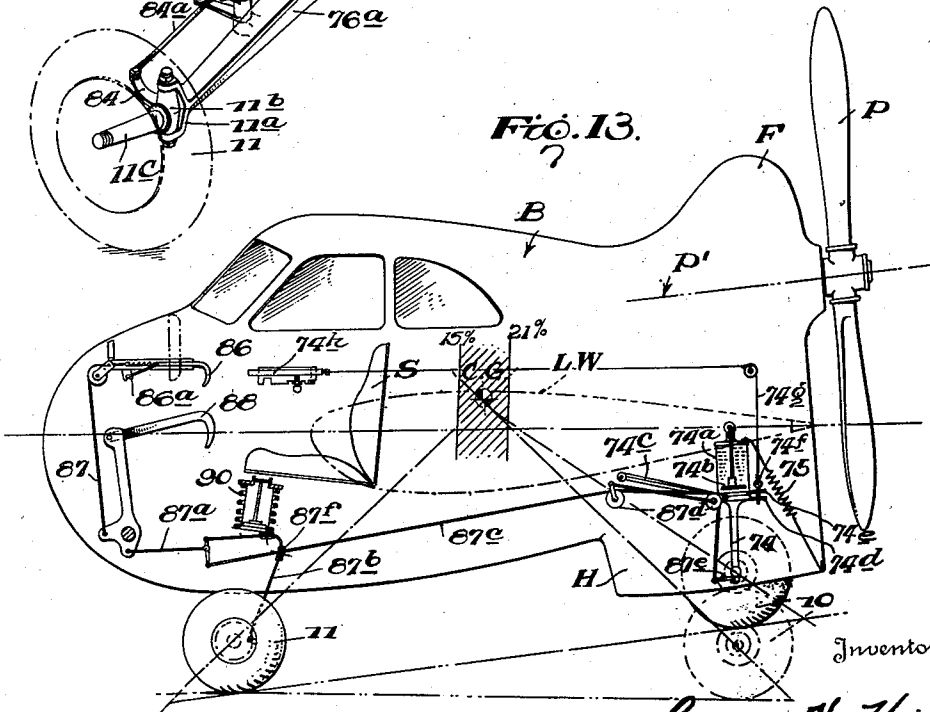
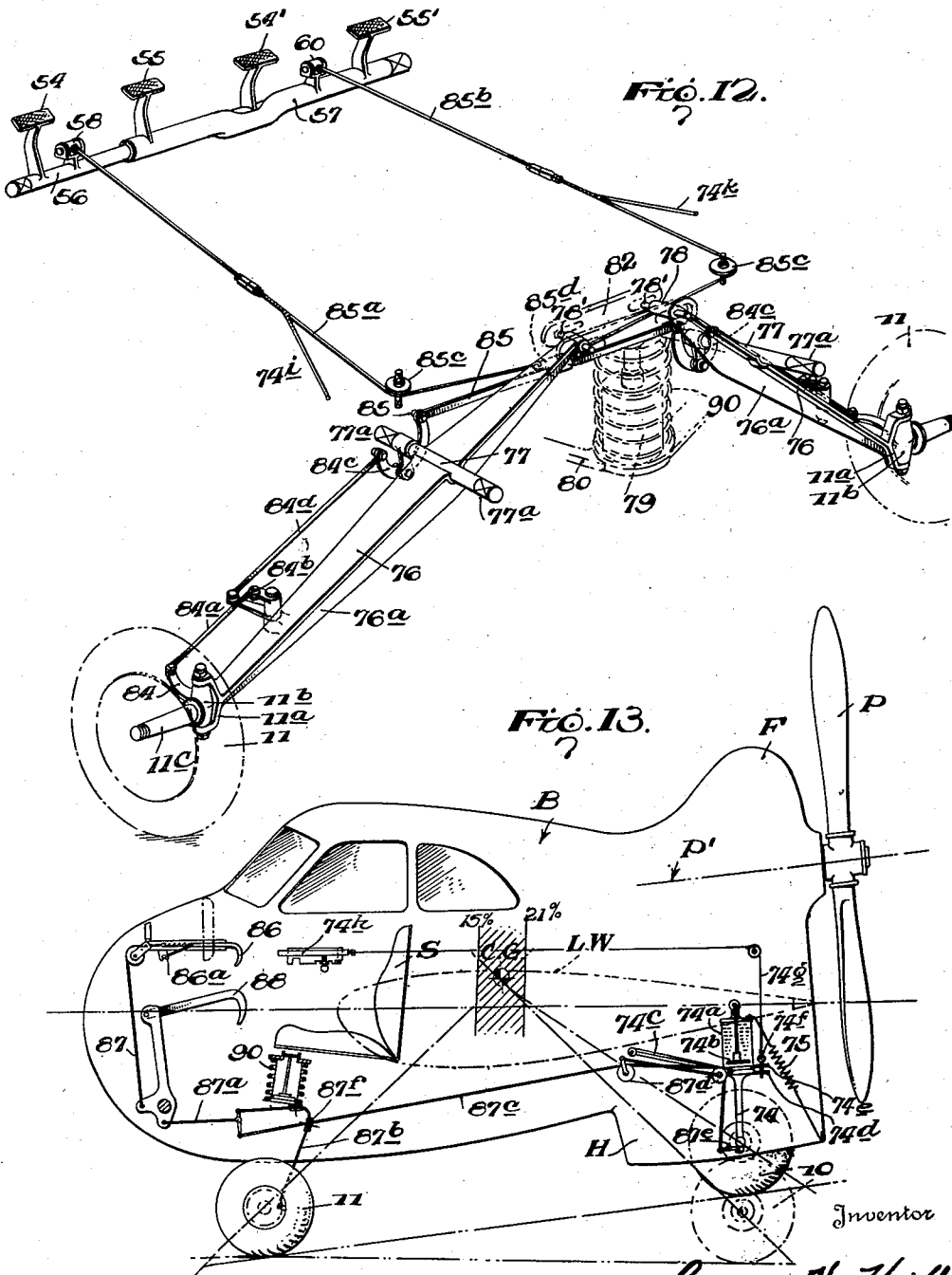
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7 Sheets-Sheet 5



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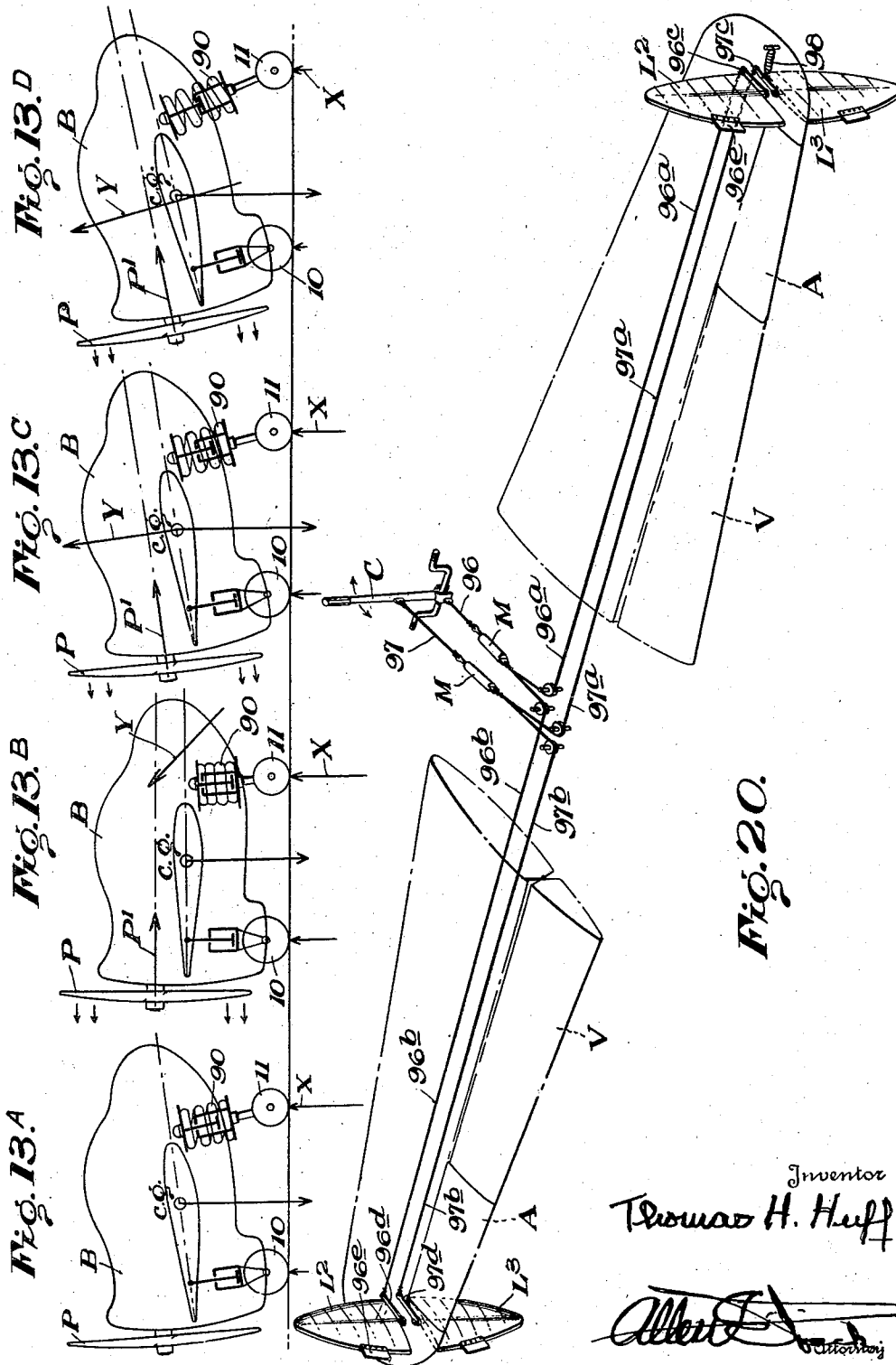
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AIRPLANE

Filed Aug. 13, 1938

7 Sheets-Sheet 6



UNITED STATES PATENT OFFICE

2,390,939

AIRPLANE

Thomas H. Huff, Merion, Pa.

Application August 13, 1938, Serial No. 224,784

44 Claims. (Cl. 244—13)

This invention relates to certain improvements in airplanes and more particularly to an airplane of a tailless type; and the nature and objects of the invention will be readily recognized and understood by those skilled in the aeronautical art in the light of the following explanation and detailed description of the accompanying drawings illustrating what I at present believe to be the preferred embodiments or aerodynamic, mechanical and structural expressions of my invention from among various other embodiments, forms, designs, arrangements, constructions and combinations of which my invention is capable within the broad spirit and scope thereof.

My present invention relates to the design of airplanes of the so-called "tailless" types and is directed to overcoming the problems and reducing the difficulties inherent in and encountered with such types. The invention is fundamentally concerned with the design of an airplane of such type that is truly tailless, that is, one in which there is no aerodynamic structure substantially to the rear of the lifting surface of the airplane and no aerodynamic structure substantially forward of such lifting surface, whether such surface be in the form of a monoplane wing or multiplane wings, so that all aerodynamic structures or elements are substantially disposed within the projected area or plan of the lifting surface and/or above or below such lifting surface. With the prevailing types of so-called tailless airplanes, various expedients, such as "sweep back" and "staggered" relation of vertically spaced multiplane wings are resorted to as substitutes for the rearwardly located tail of the conventional types of airplane, but, in a tailless design of the present invention, no such expedients are present as no substantial sweep-back or stagger of the wing or wings is utilized so that the design embodies a wing or wings having the major longitudinal or spanwise axes at substantially or approximately right angles or perpendicular to the fore and aft or longitudinal axis of the airplane.

The problems of longitudinal stability and longitudinal control of the tailless types of airplane, are fundamental ones inherent in the general type and these problems are met with in an accentuated and high degree in a tailless airplane of the type characterized by the basic design of my invention in which design such means as "sweep back" or "stagger" of the wing or wings, or other means are substantially eliminated. The basis for obtaining longitudinal

stability in a tailless airplane embodying my fundamental design, is provided by employing a lifting surface in the form of a wing or wings having an inherently longitudinally stable airfoil section, that is, a section that provides a substantial positive moment about the aerodynamic center at zero (0) lift, so that such lifting surface has a center of pressure movement in the proper directions relative to changes in the angle of attack of the lifting surface to thereby provide for the required inherent longitudinal stability throughout the flight range.

The shifting or changing of the location of the center of gravity of a tailless airplane due to the shift in weight distribution by changes in useful load is another problem inherent in the type and one that is rendered of increased importance by the present airplane of my design embodying an inherently longitudinally stable lifting surface or wing, because in a tailless airplane, incorporating such an inherently longitudinally stable wing, the practical location for the center of gravity of the airplane is within definite definable limits that are of considerably smaller range than those encountered in more conventional tailless or tailed types of airplanes. A further feature and characteristic of my present invention resides in the design of the airplane to provide such a structural and aerodynamic relationship between the longitudinally stable lifting surface or wing or wings and the other elements of the airplane, with the weight distribution and possible useful load location changes, that a predetermined but definite limited range of center of gravity location is provided for while maintaining stability and controllability within practical flight limits, and in such a manner that the center of gravity may not shift or change beyond the limitation of the said predetermined range.

Another feature of the invention in relation to changes in center of gravity location of the tailless type of airplane hereof, is found in the provision for selectively adjustably trimming the airplane longitudinally in order to compensate for changes in the center of gravity location to relieve the load on the pilot's controls that would otherwise be present.

The longitudinal controllability throughout the flight range of an airplane of the tailless type, particularly when of the truly tailless type such as provided by my present design, includes certain aerodynamic and structural problems and difficulties. One of such problems and difficulties arises from the requirement of the design

for location of all aerodynamic elements or members substantially within the plan or projected area of the lifting surface or wing, so that, whatever movable longitudinal or pitching control surfaces may be employed, such surfaces must be located substantially within the plan or projected area, and/or above or below, of the wing and preferably, although not necessarily, to the rear of the center of gravity of the airplane. With a longitudinal control surface or surfaces so located, the longitudinal or pitching control forces developed by movement thereof are applied at the wing at a relatively short distance from the center of gravity, as compared to the conventional airplane having a tail-carried longitudinal control surface, in which latter case, the longitudinal control forces are applied outside of the projected area of the wing at a considerable distance from the center of gravity of the airplane.

The application of the longitudinal control forces at the wing but a short distance from the center of gravity of the airplane, by means of a displaceable control surface or surfaces located substantially within the plan or projected area of and/or above or below the wing, results, upon initiation of the control movement of such a longitudinal control surface, in the creation of longitudinal control forces acting a short distance away from the center of gravity of the airplane and in directions that cause the airplane to be displaced in the direction opposite to that desired. This first movement resulting from such initially produced vertical control forces, is then followed by pitching movement of the airplane in the direction desired in accordance with the longitudinal control moments developed by the displacement of the longitudinal control surface. This "hunting" or adverse displacement of the airplane is a very undesirable flight condition and particularly objectionable in the handling and piloting of a tailless airplane.

The practical elimination or substantial reduction of the foregoing tailless airplane longitudinal control problems is a feature of my invention and is characterized by the provision of one form of longitudinal control system of the invention that includes a vertically displaceable longitudinal control surface or surfaces substantially within the projected area or plan of the wing or lifting surface for developing the required pitching moments acting in the desired directions, together with means in the form of a vertically displaceable surface substantially within the projected area of the wing for displacement in such relation to any particular direction and degree of displacement of the longitudinal control surface, as to neutralize or substantially eliminate or reduce the adverse vertical control forces developed by the displacement of the longitudinal control surface, so as to thereby reduce the undesirable conditions above pointed out as inherent in such longitudinal control of a tailless airplane of the types referred to herein.

I have discovered and determined that the neutralization or reduction in the undesirable adverse vertical control forces developed by vertical displacement of the longitudinal control surface or surfaces, by the use of another vertically displaceable surface or surfaces, requires a varying relative angular relation between a control surface and such a force neutralizing surface, which relationship basically requires displacement of the neutralizing surface in the opposite direction from that in which the control surface

is displaced; and further that the ratio or relation between the opposite angles at which these movable surfaces are respectively displaced relative to the wing or lifting surface, varies in accordance with other flight conditions, such as the angle of attack of the wing or lifting surface and the direction of displacement of the longitudinal control surface, that is, whether such latter surface is displaced to a positive or negative angle relative to the lifting surface.

Another feature of my invention is the provision of a design and arrangement of longitudinal control system functioning in accordance with the foregoing principles and by which the varying relation between the angular displacements of a longitudinal control surface and a vertical control force neutralizing surface may be obtained as required in accordance with and under the varying flight conditions, through the medium of adjustment of the angular displacement and direction of displacement of the neutralizing surface relative to the angular displacement and direction of displacement of the longitudinal control surface.

My invention further provides in the practical applications and adaptations of the basic longitudinal control principles of the foregoing form of longitudinal control of my invention, for either mounting a vertically displaceable longitudinal control surface on and carried by a vertically displaceable vertical control force neutralizing surface, with the latter surface independently adjustable relative to the control surface, or, in independently mounting the longitudinal control surface and the neutralizing surface on the wing, with the latter surface displaceable or adjustable to determine its angle of displacement and direction of displacement relative to that of the control surface independently of displacement of the control surface; and, as a further feature in providing, if desired, for utilizing such neutralizing surfaces as ailerons or roll control surfaces without interfering with their operation as neutralizing surfaces per se.

In accordance with a further feature of the invention, in connection with those forms of the longitudinal control that embody a displaceable longitudinal control surface and a vertically displaceable control force neutralizing surface, these surfaces are coincidentally, but differentially operated for longitudinal control by a suitable control operating mechanism, but when such surfaces are so coincidentally and differentially operated, the forces acting upon the pilot's control are reversed and therefore, following a further feature and characteristic of the invention, a form of irreversible control mechanism or some other form of mechanical and/or aerodynamical means for reversing the forces on the pilot's control is utilized.

The longitudinal control, following a further feature of the invention, may be provided by vertically disposed laterally displaceable control surfaces mounted at or adjacent the opposite wing tips and located above and below the wing, respectively, with the opposite surfaces above the wing operable independently of the opposite surfaces below the wing, together with suitable control operating mechanism for selectively simultaneously laterally displacing in the opposite directions, either the control surfaces above the wing or the control surfaces below the wing, in order, in the former case, to establish stalling moments, and, in the latter case, diving moments, for the purpose of longitudinally controlling the

airplane. This form of control likewise affects the lift on the airplane in the opposite direction to that desired and therefore, it is desirable to have some form of vertical control force neutralizing surface or surfaces which can be operated in any suitable manner to aerodynamically cooperate with the longitudinal control surfaces in order to eliminate or reduce such adverse forces.

Another feature of the invention resides in the design and arrangement of directional or yaw control for airplanes of the tailless types, and particularly the truly tailless type of the basic design of my present invention; and this feature is characterized fundamentally by the provision of opposite wing tip rudders located substantially within the plan or projected area of the lifting surface or wing and laterally displaceable about vertical axes, together with an operating control system that provides for selective displacement of either wing tip rudder alone without displacement of the opposite rudder for directional or yaw control; and resides further in the provision for the design and location of such rudder surfaces so that upon operation of either of them, the displaced rudder surface functions primarily to establish drag at its respective wing tip without causing any appreciable change in lift on the wing even with the displacement of the rudder establishing a stalling moment at such wing tip.

In connection with the directional control provided by the wing mounted rudders, the invention is characterized by the elimination of any fixed vertical fin surface as a part of the rudder and as distinguished from tip loss shields or surfaces or other remotely mounted fixed vertical surfaces for directional stability; and is further featured by the design of a rudder surface to provide a cambered section having the side of greatest camber positioned inboard.

A further feature of the invention resides in the elimination of the directional or yaw control surfaces and the utilization of the ailerons or roll control surfaces for the dual function of roll control and directional or yaw control, thereby providing for flight operation of the tailless airplane of my basic design by only two controls.

The design, arrangement and mounting of a landing gear for a tailless type of airplane presents certain problems and difficulties due to the limitations on location imposed by the tailless design and especially by a design of the truly tailless type such as disclosed herein where it is desirable to avoid locating any structure appreciably outside of the plan or projected area of the lifting surface. An important feature of my invention is presented by a design, arrangement and mounting of a landing gear primarily adapted to the conditions met with in the truly tailless type of airplane hereof but which is of general application to other aircraft as well, in which landing gear the rear landing surface engaging element or elements is located within the projected plan or area of the wing while the forward landing surface engaging elements are located spaced a minimum distance forwardly from the leading edge of the wing, and which rear and forward landing surface engaging elements so positioned have a definite location relative to the center of gravity of the airplane and the range of center of gravity movement, which location is preferably equidistant from the center of gravity so that any tendency of the airplane to nose over backward is substantially eliminated.

The landing gear of the invention is also fea-

tured by an arrangement which provides the forward ground engaging elements as spaced apart laterally and mounted for vertical displacement under landing and taxiing loads and forces, but which forward elements are so operatively associated with each other and with a common shock absorbing unit that vertical displacement of one element is necessarily accompanied by positive corresponding vertical displacement in the same direction of the other elements and independent vertical displacement of such ground engaging elements is thereby prevented, so that the airplane tends to always maintain its normal horizontal attitude laterally.

As a further feature of this invention, the design and arrangement of the landing gear provides for inherent directional stability while moving forward on the ground, due to the location of the center of gravity intermediate the forward and rear ground engaging elements with the rear element or elements normally directionally fixed and the forward element or elements of the landing gear mounted for castering so that upon ground contact in landing or in taxiing the airplane supported by such landing gear will always assume and maintain its direction of movement rather than its direction of heading.

The tailless types of airplanes also present serious take off problems and difficulties which are accentuated in the truly tailless type in which no aerodynamic elements are located substantially to the rear or forward of the lifting surface or wing, due to the practical impossibility of developing moments acting about the center of gravity of the airplane in order to change the ground supported attitude thereof and place the wing or wings or lifting surface at a sufficient angle of attack to develop a lift coefficient of a magnitude required for taking the airplane off. Thus, the angle of attack of the lifting surface or wing can not be sufficiently increased for take off and it either becomes impossible at the ground supported attitude of the airplane to acquire sufficient speed to develop the required lift from the wing at its angle of incidence for the ground supported position of the airplane, or, an excessively long ground run is required in order to attain the necessary speed to develop the required take off lift.

An important feature of my invention is directed to the elimination of the take off difficulties encountered with the tailless types of airplanes due to the presence of the above referred to general conditions, which feature is not only adapted to the tailless types but to airplanes generally, and which fundamentally and basically embodies a relative arrangement and location of the center of gravity, the ground engaging elements of the landing gear, the horizontal attitude of the body and the angle of incidence of the lifting surface fixed relative thereto, together with the line of thrust where this thrust is above the center of gravity, such that as the thrust force is applied for take off, a moment is established acting around the center of gravity tending to nose the airplane down, but as forward speed increases, the lift developed by the wing is increased, and due to the fact that the wing is inherently longitudinally stable, this lift acts upwardly and forward of the center of gravity producing a stalling moment at small angles of attack which counteracts the thrust moment so that the load on the forward elements of the landing gear is thereby reduced and the angle of attack increased up to that

angle at which the lift force on the wing coincides with the center of gravity. Due to the fact that this coincidence may occur at an angle of attack less than that desired for take off, it is necessary to incorporate some additional mechanical means of increasing the angle of attack still further; and a further characteristic of this feature of the invention resides in providing a constantly acting upward force or forces of a required magnitude tending to raise the forward portion of the body and wing of the airplane relative to the forward ground engaging elements of the landing gear in a manner to increase the angle of attack of the wing to such an angle that the required lift for take off may be developed.

Another feature of the invention resides in the provision of drag creating members to function as air brakes and in providing such members in a definite relation and association with the wing and the contour lines of opposite sides of the body and the airflow to the propeller in order that such drag creating members may function without interfering with airflow past the body and to the propeller, while in fact tending to increase the efficiency of such flow and to decrease propeller noise; and further in providing such members of a design and a location on the wing such than when operated the members establish a stalling moment for landing.

Another feature of the invention resides in providing an improved and efficient pilot operated steering mechanism for the forward castering ground engaging elements or wheels of the landing gear.

The invention further provides as a feature thereof, for the efficient cooling of an aircooled motor located at the rear of the airplane and enclosed from the airflow; and this feature is characterized by an arrangement of cooling air ducts or passages leading from the forward end or nose of the body to the motor and discharging downwardly and rearwardly through the fairing or housing structure for a rear ground engaging element of the landing gear, whereby during flight a suction force is established at the discharge end and a positive pressure at the intake end of such passages to thereby circulate air rearwardly therethrough for cooling the motor.

A further feature of the invention in connection with such cooling system provides for the automatic operation from the motor of a fan or blower for circulating air through said passages when the airplane is on the ground either at rest or taxiing and for disengaging such fan or blower when the airplane leaves the ground.

With the foregoing general features, characteristics and results in view, as well as certain others that will be readily recognized from the following description, my invention consists in certain novel features in design, arrangement, combination and construction of elements and parts, all as will be more fully and particularly referred to and specified hereinafter.

Referring to the accompanying drawings in which similar reference characters refer to corresponding parts throughout the several figures:

Fig. 1 is a view in top plan of a tailless airplane embodying the design and various features of my invention.

Fig. 2 is a view in front elevation of the airplane of Fig. 1.

Fig. 3 is a view in side elevation of the airplane of Figs. 1 and 2.

Fig. 4 is a transverse vertical section through the wing of the airplane of Fig. 1 showing the mounting and associated control mechanism for the adverse control lift neutralizing surface and the vertically displaceable longitudinal control surface pivotally mounted along the trailing edge thereof.

Fig. 5 is a detailed view in side elevation of the unit for reversing the motion applied to concentric control pedal shafts.

Fig. 6 is a rear end elevation of the reversing unit of Fig. 5.

Fig. 7 is a more or less schematic view in perspective of the operating mechanism for the longitudinal control surfaces and adverse lift neutralizing surfaces where the former surfaces are mounted on the neutralizing surfaces and the neutralizing surfaces are independently adjustable relative to the control surfaces.

Fig. 8 is a more or less schematic view in perspective of the operating mechanisms for the longitudinal control surfaces and adverse lift neutralizing surfaces where the latter surfaces are mounted on the wing independently of the longitudinal control surfaces and are also operable differentially as ailerons or roll control surfaces.

Fig. 9 is a detail view of a portion of a modified form of longitudinal control surface and neutralizing surface operating mechanism of the irreversible type in which such surfaces are co-incidentally and differentially actuated.

Fig. 10 is a perspective view more or less diagrammatic showing the opposite wing tip rudders and their mounting, together with the operating control system therefor including the control pedals and showing in dotted lines a control position of the right wing tip rudder and the associated pedals.

Fig. 11 is a more or less diagrammatic view in perspective showing the opposite wings and the spaced laterally swingable air brake surfaces with the operating mechanism therefor.

Fig. 12 is a view in perspective showing the forward castering landing wheels of the landing gear and the vertically swingable supporting struts or legs therefor associated at their inner ends with the common shock absorbing unit and force exerting spring acting thereon, together with the operating mechanism for arbitrarily steering said forward castering landing wheels.

Fig. 13 is a view in side elevation more or less schematic showing the body of the airplane in outline and indicating the center of gravity location relative to the landing gear wheels, and further showing the arrangement of operating system for the forward and rear wheel brakes, and also showing more or less diagrammatically the mounting of the rear wheel of the landing gear and its associated shock absorbing unit.

Figs. 13A, 13B, 13C and 13D, are purely schematic views in outline indicating progressively the altitude of the airplane and the directions of the various forces acting thereon during certain period of take-off, from ground position with engine off, to the moment of take-off.

Fig. 14 is a view in side elevation of the airplane of Figs. 1 to 3 and showing the air circulating ducts or passages of the engine cooling system together with the engine driven fan or blower for mechanically circulating air through such ducts or passages while on the ground, and a form of automatic means for disengaging the blower while the airplane is in the air.

Fig. 15 is a detail view in front elevation show-

ing the air duct or passage intake at the forward or pressure end of the body.

Fig. 16 is a detail view partly in vertical section showing the construction and arrangement of means for circulating cooling air over an engine exhaust pipe.

Fig. 17 is a detail view in vertical section through a cable slack take up unit as employed in certain of the control operating systems of the invention.

Fig. 18 is a view in vertical section through the forward or front wheels and their vertically displaceable supporting legs or struts in operative connection with the common centrally located shock absorbing unit and force exerting spring.

Fig. 19 is a view similar to Fig. 18, but showing the force exerting spring, shock absorbing unit, and wheel struts in their positions with the airplane supported on the ground.

Fig. 20 is a perspective view, more or less diagrammatic, showing a form of longitudinal control and operating system therefor embodying vertical opposite wing tip mounted laterally displaceable control surfaces above and below the wings.

A truly tailless airplane embodying the basic design and various features of my invention is illustrated by way of example and not in all respects of limitation, in the accompanying drawings, and while the various features of the invention are of particular utility and efficiency in overcoming and reducing the problems and difficulties of the tailless types of airplanes, it is to be understood that certain features are not only adaptable to and useful with other types of tailless airplanes, but aircraft generally, and such general adaptability of any such features will be referred to hereinafter in the detailed descriptions thereof.

The illustrated embodiment hereof of my basic design and arrangement of tailless airplane, referring now particularly to Figs. 1, 2 and 3 of the drawings, includes a body or fuselage B of streamline form and, in the example hereof, of enclosed cabin type providing the occupant space or compartment which includes preferably, although not necessarily, a side-by-side seating arrangement as indicated by one of such side-by-side seats S shown in Fig. 13 of the drawings. This body B may be of any suitable or desired construction and includes, referring now to Fig. 14 of the drawings, a suitable enclosed space or compartment therein to the rear of the occupant compartment for receiving and housing the engine E in the upper portion thereof for driving, in the present instance, a pusher propeller P.

The body B may, as in the example hereof, include and provide at its rear upper side, an upwardly projecting vertical fin forming structure F. At its lower rear side, the body B is provided with a depending housing or fairing H for the rear wheel 10 of the landing gear and as an outlet for the engine cooling air. The upper vertical fin F and the depending housing or fairing H therebelow provide vertical fin area contributing to directional stability of the airplane.

The body B is mounted upon and carried by a landing gear that includes the rear ground engaging element or wheel 10 located within the housing or fairing H, which rear wheel is disposed in the vertical plane of the longitudinal or fore and aft axis of the body B, and the forward landing wheels 11 spaced apart laterally of the body and located and positioned at opposite sides thereof spaced outwardly a considerable distance

therefrom in order to provide a relatively wide tread. The rear wheel 10 is directionally fixed and vertically displaceable, while the forward wheels 11 are vertically displaceable and mounted for castering or lateral swinging for providing directional stability in cooperation with the rear directionally fixed wheel 10, and for arbitrarily steering the airplane on the ground in accordance with the fundamental principles of the landing gear design of the invention.

The lifting surface of the airplane is provided by the wings RW and LW extending laterally from opposite sides of the body B, and, in the example hereof, of monoplane form, although obviously, the invention is not limited or restricted to the use of monoplane wings as it contemplates and includes various multiplane wing arrangements within the fundamental requirements of the invention if desired or found expedient.

Inherent longitudinal stability

In the example hereof, the opposite wings LW and RW include the inner or root ends thereof formed by the center section wing panel providing the opposite wing stubs RW' and LW' in accordance with more or less usual design and constructional practice, and the wings are mounted and fixed to the body in the example hereof at approximately zero (0) degrees dihedral. The wings RW and LW are disclosed in Fig. 2 of the drawings as at approximately zero (0) degrees dihedral.

The wings RW and LW forming the lifting surface of the airplane are mounted in position relative to the body B such that the trailing edges of the wings, in this instance, are at substantially right angles or perpendicular to the longitudinal axis of the body and are located substantially in line with the rear end of the body so that the wings or lifting surface have no substantial rearward projection beyond the tail end of the body, or the body has no substantial projection rearwardly beyond the trailing edges of the wing. The lifting surface or wings RW and LW are of inherently longitudinally stable type and are without any substantial sweep back in the present instance, and in accordance with the truly tailless design of the invention, the lifting surface should have no appreciable sweep back but should preferably have its major medial longitudinal or spanwise axis approximately at right angles or perpendicular to the fore and aft or longitudinal axis of the body B and the airplane, although it is to be here pointed out that a design of my invention may, if desired, include some degree of sweepback for the purpose of physically balancing the airplane, but not for the primary purpose of securing aerodynamic stability per se.

The supporting surface or wings RW and LW for the airplane are, in accordance with a basic characteristic of the invention, of an airfoil section such that these wings are inherently longitudinally stable, that is, a wing section which provides a wing having a substantial positive moment about the aerodynamic center at zero (0) lift, that is, a wing section with a substantial positive value C_{mo} .

The leading edge of the lifting surface formed by the wings RW and LW is located to the rear of the forward or nose end of the body B and, in the particular example hereof, a slight distance to the rear of the forward wheels 11 of the landing gear, as will be clear by reference to Figs. 2 and 3 of the drawings in particular, although this

is not an essential or critical factor in the design. It so happens that in the particular design illustrated, the leading edges of the wings RW and LW have an outward rearward inclination to provide the normal taper of a cantilever wing.

Lateral or roll control

The lateral or roll control for the design of tailless airplane of Figs. 1 to 3 may be of any suitable or desired type but in this instance is disclosed as a more or less conventional control embodying the opposite wing ailerons or angularly vertically displaceable surfaces A forming trailing portions of the wing or lifting surface and adapted for operation through a suitable control operating mechanism. The ailerons A are mounted for a distance along the outer or tip portion of the span of the wings RW and LW and an operating mechanism is provided, referring now to Fig. 8 of the drawings, which includes the usual pilot's control stick or other manually operable control member C mounted for lateral swinging or movement for aileron actuation and coupled by means of a torque tube 14 for transmitting such lateral rocking of the control stick through the connected opposite push-pull tubes 15 and 16 to the opposite wing ailerons A. The outer end of push-pull rod 15 is connected with a bell crank 17, which bell crank is coupled by a link 17a with the adjacent aileron A, while the outer end of the push-pull rod 16 is coupled with a bell crank 18 mounted in the wing LW and coupled with the aileron A of such wing by a link 18a. This arrangement of operating mechanism for the opposite wing ailerons A, while only shown in Fig. 8 of the drawings, is adapted for operating the opposite wing ailerons A of Figs. 7 and 9, in order to obtain the usual actuation of those ailerons for lateral or roll control. However, the invention is not concerned with the specific operating mechanism for the ailerons or other roll control surfaces.

Preferably, each of the ailerons or roll control surfaces A is provided with a suitable trimming tab or trailing surface a mounted thereon and vertically angularly adjustable relative to the aileron. Such a tab a is shown on an aileron A of Fig. 1 of the drawings.

Longitudinal or pitch control

The longitudinal or pitch control of my invention, adapted particularly for the conditions presented by the tailless type of airplane, is disclosed in one form and adaptation thereof in Fig. 7 when considered in connection with Fig. 1 of the drawings. This longitudinal control embodies the hereinbefore referred to principles of my invention by which longitudinal control or pitching moments are developed acting about the center of gravity of the airplane for longitudinal or pitching control thereof, and provides for reducing or substantially eliminating the adverse vertical lift resulting from the actuation of the longitudinal control surfaces L.

The longitudinal control surface or surfaces may be, as in the present example, in the form of vertically angularly displaceable trailing portions of the lifting surface or wings of the airplane, such as surface L providing the trailing portion of each of the wings RW and LW along the span thereof. Each of these longitudinal control surfaces L is vertically angularly displaceable by means of a suitable operating mechanism to positive or negative angles relative to the lifting surface or wing in order to establish the desired longitudinal control or pitching moment acting in the

required direction about the center of gravity of the airplane. The opposite wing longitudinal control surfaces L are simultaneously displaced to obtain the required longitudinal control, and, as heretofore pointed out, the displacement of these control surfaces develops adverse lift so that if these control surfaces L are displaced downwardly to cause the airplane to dive, then, upon initiation of this control movement, the adverse lift established will cause the airplane to rise. In the same manner, as the longitudinal control surfaces L are upwardly displaced so as to cause the airplane to pitch about the center of gravity in the direction of stall, then the reverse action takes place and the airplane is caused to sink by the adverse lift.

In accordance with my invention, provision is made for reducing or neutralizing these adverse lifts, caused by operation of the longitudinal control surfaces L. In the present expression of this feature of my invention, I have provided adverse lift neutralizing surfaces V in the form of vertically angularly displaceable surfaces forming portions of the lifting surface or wings of the airplane and I have mounted one such surface V on each of the wings RW and LW disposed spanwise thereof, with each surface V hinged along a hinge axis 20 (see Fig. 7) between its leading edge and the trailing edge portion of the fixed wing structure there-ahead.

In the form of the longitudinal control arrangement of Figs. 1 and 7, the longitudinal control surfaces L are mounted on and carried by the neutralizing surfaces V, respectively, each longitudinal control surface L being hinged along a hinge axis 21 to the trailing edge of a surface V so that the connected neutralizing surface V and longitudinal control surface L of each wing, form vertically displaceable trailing portions of the wing and in their normal neutral positions carry out and define the normal airfoil section and contour of the wing.

For longitudinal control, the adverse lift neutralizing surfaces V of the opposite wings are simultaneously vertically displaced independently of displacement of surfaces L, into angular positions relative to the wings at angles relative to the angle of vertical displacement of the said longitudinal control surfaces L, and in directions opposite the direction of displacement of such longitudinal control surfaces. Suitable mechanism is provided for simultaneously angularly vertically displacing the neutralizing surfaces V about their hinge axes 20 and independently of the displacement of the longitudinal control surfaces, so that the adverse lift neutralizing surfaces V may be adjustably displaced arbitrarily by the pilot.

A form of operating and control mechanism for the adverse lift neutralizing surfaces V is more or less diagrammatically disclosed in Fig. 7 of the drawings and embodies a shaft or rotatable member 22 mounted in suitable bearings 22a with this shaft disposed intermediate the opposite wings RW and LW and transversely of and through the center section RW' and LW', and the body B. This shaft 22 is provided with internally threaded axial bores at its opposite ends with the threads of these opposite end bores oppositely threaded, that is, one bore having a right-hand thread and the other a left-hand thread. A threaded rod 23 is provided extending axially into and engaged by the threaded bore at the right-hand end of shaft 22, and a similar

threaded rod 24 extends axially into and engages the threaded bore at the left-hand end of the shaft 22. The opposite end threads of the shaft bores and the threads of the opposite rods 23 and 24 are arranged so that upon rotation of shaft 22 in one direction, the rods 23 and 24, which are held against rotation, but which are free to move axially, are simultaneously moved into the shaft, while upon rotation of the shaft in the opposite direction, these rods are simultaneously moved outwardly from the ends of the shaft.

A bell crank 23a is mounted within the wing RW forward of the neutralizing surface V of that wing, and one arm of this bell crank is connected by a link 25 with the outer end of rod 23, there being a universal joint 25a connecting the inner end of link 25 with rod 23. The other arm of bell crank 23a is coupled with a depending undersurface horn 26 on surface V by a link 26a. In the left-hand wing LW, there is provided a bell crank 24a forward of the neutralizing surface V of that wing and one arm of this bell crank is connected with the outer end of rod 24 by a link 27 through a universal joint 27a. The other arm of the bell crank 24a is coupled with a depending horn 28 in surface V by a link 28a.

The arrangement of the opposite wing bell cranks 23a and 24a with the linkage coupling the surfaces V through these cranks to the opposite rods 23 and 24 in the shaft 22 is such that upon rotation of shaft 22 in one direction, the rods 23 and 24 are simultaneously drawn inwardly to simultaneously raise or vertically angularly displace the opposite wing neutralizing surfaces V, while rotation of shaft 22 in the opposite direction will simultaneously force the opposite rods 23 and 24 outwardly from shaft 22 and thus simultaneously lower or angularly displace the opposite wing surfaces V downwardly.

A pilot controlled and operated mechanism is provided for selectively rotating shaft 22 in either direction in order to raise or lower the adverse lift neutralizing surfaces V of the opposite wings RW and LW, and such mechanism may, as in the example hereof, take the form of a shaft 29 rotatable by a hand crank 30 and having fixed thereon a sprocket or gear 31. A sprocket or gear 32 is fixed on shaft 22 and is operatively connected with the sprocket or gear 31 of operating shaft 29 by means of a suitable chain 33. The shaft 29, with its operating hand crank 30, is mounted at a suitable location in the body B readily accessible to the pilot, and a visual indicating mechanism may be included that embodies a rack 34 engaged by the gear or sprocket 31 and carrying an indicator pin or pointer 35 for actuation by rotation of gear 31 to indicate the direction and degree of vertical displacement of the adverse lift neutralizing surfaces V.

In the form and arrangement of longitudinal control of Fig. 7, in which the opposite longitudinal control surfaces L are mounted on and hinged to the opposite neutralizing surfaces V, respectively, along the hinge lines 21, the operating mechanism for the longitudinal control surfaces L is, of course, coupled with and actuated by the pilot's control stick C. In this instance, such mechanism includes a vertically disposed lever 36 mounted on each wing RW and LW intermediate or between a neutralizing surface V and the forward portion of the wing structure for rocking about an axis 36a intermediate its ends coincident with the hinge axis 20 of each respective surface V. The upper arm of each

crank 36 is connected to a longitudinal control surface L rearwardly thereof by means of a link 36b. The lower arm of crank 36 of wing RW is connected with an arm of bell crank 37 mounted in the wing forward of surface V, by a link 37a, and the lower arm of lever 36 of wing LW is connected by a link 38a with an arm of a bell crank 38 mounted in wing LW forward of its neutralizing surface V.

A bell crank 39 is mounted at a suitable location intermediate the wings RW and LW and has its opposite arms operatively connected with the opposite wing bell cranks 37 and 38 between push-pull rods 39a and 39b. The bell crank 39 is rocked by and from longitudinal or fore and aft rocking movement of the pilot's control stick C through the medium of a link or a push-pull rod 40 connecting the stick C with an arm of the bell crank 39. Thus, forward movement of the control stick C simultaneously lowers or downwardly angularly displaces the opposite longitudinal control surfaces L while rearward movement of the control stick C simultaneously raises or angularly displaces the longitudinal control surfaces L upwardly, the angular displacement upwardly or downwardly of these surfaces L taking place about the hinge axes 21 thereof along the trailing edges of the opposite neutralizing surfaces V.

The arrangement of the operating mechanism for the opposite longitudinal control surfaces L, with the levers 36 of such mechanism rocking about the hinge axes of the neutralizing surfaces V, respectively, upon which surfaces the longitudinal control surfaces are mounted in trailing position, enables vertical angular displacement of the longitudinal control surface independently of and without effecting displacement of the neutralizing surfaces, notwithstanding the positions to which such latter surfaces may have been adjusted.

The vertical displacement upwardly or downwardly of the adverse lift neutralizing surfaces V is accomplished by the operating mechanism therefor as heretofore described, by rotation of the hand crank 30 in the required direction to raise or lower the surfaces V, and such adjustment of surfaces V is carried out independently of the longitudinal control movements of the surfaces L by the fore and aft rocking movement of the control stick C. It is to be noted at this point that the operating mechanism for simultaneously vertically displacing the neutralizing surfaces V, is of the irreversible type provided by the threaded rods 23 and 24 engaged in the threaded shaft 22 so that this operating mechanism will maintain the neutralizing surfaces V in an angularly adjusted position against displacement and without requiring the application of any forces by the pilot to maintain the surfaces in their adjusted position.

In the flight operation of the longitudinal control surfaces L, and the adverse lift neutralizing surfaces V, in the particular design of tailless airplane here shown as an example, I have discovered and determined that there is a varying ratio throughout the flight range between the angle to the wing or lifting surface at which the longitudinal control surfaces L are displaced and the opposite angle at which the neutralizing surfaces V are displaced in order for the latter to neutralize or reduce the adverse lift developed by the displacement of the surfaces L. As hereinbefore pointed out, the surfaces V, in order to function to neutralize or reduce the adverse

lift, must be displaced in a direction opposite the direction of displacement of the longitudinal control surfaces L, that is, when the longitudinal control surfaces are displaced to a positive angle as for a dive, then the neutralizing surfaces are displaced to a negative angle, while if the longitudinal control surfaces are displaced to a negative angle to cause the airplane to stall, then the neutralizing surfaces are displaced to a positive angle relative to the lifting surface.

The relationship between the angle of a neutralizing surface and the opposite angle of displacement of a longitudinal control surface varies with the angle of attack of the lifting surface or wings of the airplane, and also, this relationship between the opposite angles of these surfaces varies in accordance with the direction of displacement of the longitudinal control surface, that is, as to whether the surface is displaced to a positive or negative angle. For example, at high angles of attack of the lifting surface or wings, in general, in order to neutralize or compensate for adverse lift, it is necessary to displace the neutralizing surfaces to larger angles, both positive and negative, than at low angles of attack, and in this high angle of attack condition, with the longitudinal control surfaces at negative angles, it is necessary to displace the neutralizing surfaces to slightly larger positive angles than when the control surfaces are at positive angles. At low angles of attack of the lifting surface or wings, I have found that the neutralizing surfaces may be moved to smaller positive than negative angles in order to neutralize or compensate for the adverse lift developed by the displacement of the longitudinal control surfaces to negative and positive angles, respectively. I have also determined in connection with the above, that for the condition of no variation in the lift force, the moment is greater for positive angles of the longitudinal control surfaces, that is, for the dive condition, than for the negative angles of the longitudinal control surfaces, that is, for the stall condition. At low angles of attack of the lifting surface or wings with the lift force unchanged, the resulting moment is greater for the negative angles of displacement of the longitudinal control surfaces representing the stalling moment than the resulting moment is for the corresponding positive angles of displacement representing the dive moment.

With the independently operable adverse lift neutralizing surfaces V of the arrangement of Fig. 7, the pilot, upon displacement of the longitudinal control surface L for longitudinal control, may then, by rotation of the hand crank 30 in the proper direction, displace the neutralizing surfaces in a direction opposite to that of the displacement of the longitudinal control surfaces and at a relative angle that may be required in order to neutralize the adverse lift developed by the displacement of the longitudinal control surfaces. This independent operation and adjustment of the neutralizing surfaces thus enables the pilot to displace and adjust such surfaces in accordance with the flight conditions, including angle of attack of the lifting surface or wings and direction and degree of displacement of the longitudinal control surfaces.

These vertically angularly displaceable adverse lift neutralizing surfaces V and the irreversible operating mechanism therefor, may be utilized for the purpose of longitudinally trimming the airplane to compensate for changes in the center of gravity location resulting from shifts

or variations in the weight distribution of the useful load. The adjustment of the neutralizing surfaces V for purposes of longitudinal trim, may be carried out independently of and without interfering with the longitudinal control operation of the surfaces L mounted on the neutralizing surfaces, such surfaces L, being operable in any position to which surfaces V are displaced or adjusted. Upon adjustment of the neutralizing surfaces V to a displaced position, for longitudinal trim, these surfaces may then be operated from the adjusted position for purposes of neutralizing adverse lift.

Longitudinal trim may also be obtained by a lifting surface or wing camber varying operation of the longitudinal control surfaces and the neutralizing surfaces, with those forms of the invention in which the longitudinal control surfaces are mounted on and carried by the neutralizing surfaces, through displacement of the longitudinal control surfaces and the neutralizing surfaces in the same direction. For example, with the longitudinal control system and arrangement of Fig. 7, by displacing the neutralizing surfaces V and longitudinal control surfaces L in the same direction, the camber of that portion of the span of the wing occupied by such surfaces is changed and the airplane may be trimmed longitudinally by such camber change. After such a wing camber varying displacement of the longitudinal control surfaces and the neutralizing surfaces, with the arrangement of Fig. 7, the operation of the longitudinal control surfaces the cooperative independent displacement of the neutralizing surfaces, as hereinbefore explained, may then be carried out for longitudinally controlling the airplane.

Attention is here directed to the fact that in the selection of an inherently longitudinally stable wing, there is available a large selection of ranges of center of gravity location.

For example, with such inherently longitudinally stable wings having a positive C_{mo} moment, that is, a moment having a value of from 0 to $+.020$, there is available a very large degree of controllability within the flight range due to the small inherent stabilizing moments.

Nevertheless, it is a fact that in order to maintain stability in the flight range, the location of the center of gravity is limited to a range of approximately three per cent (3%) of the mean aerodynamic chord, making it difficult to practically utilize these wing sections, except where the variation in useful load limits the range of the center of gravity to approximately three per cent (3%) of the mean aerodynamic chord.

With such wings having a substantial positive C_{mo} moment, that is, such a moment having a value in the range from $+.020$ to $+.045$, there is available a smaller degree of controllability within the flight range due to the larger inherently stabilizing moments. Nevertheless, it is a fact that in order to maintain stability in the flight range, the location of the center of gravity is limited to a range approximately six per cent (6%) of the mean aerodynamic chord, making it possible to practically utilize these wing sections where the variation in the useful load limits the range of the center of gravity to approximately six per cent (6%) of the mean aerodynamic chord.

Such wings having a large positive C_{mo} moment, that is, such a moment having a value in the range from $.045$ upwards, there is available a very much smaller degree of controllability

within the flight range due to the much larger inherent stabilizing moments. Nevertheless, it is a fact that in order to maintain controllability in the flight range the location of the center of gravity is limited to a range of approximately three per cent (3%) of the mean aerodynamic chord, making it difficult to practically utilize these wing sections except where the variation in useful load limits the range of the center of gravity to approximately three per cent (3%) of the mean aerodynamic chord.

Therefore, a feature and characteristic of my present invention is in the discovery that the wing having such characteristics and range of center of gravity location may be employed with and as an element of a tailless airplane to obtain certain important and highly advantageous results from the standpoint of flight control and of structural design and weight distribution. Therefore, as a preferred condition, I utilize an inherently stable wing having a substantial or appreciable positive C_{mo} moment, for example, such a moment having a value in the range from .020 to .045 permitting a range of center of gravity location of approximately six per cent (6%) or from fifteen (15) to twenty-one (21) per cent, measured along the mean aerodynamic chord of the wing from the leading edge thereof.

In Fig. 8 of the drawings, another form and arrangement of longitudinal control is disclosed employing the basic principles of the longitudinal control in the form of Fig. 7, but, mounting the longitudinal control surfaces on fixed structure of the wings or lifting surface instead of on the neutralizing surfaces.

Referring to Fig. 8, the longitudinal control surfaces L' are mounted upon the opposite wings RW and LW as vertically displaceable trailing portions of the wing extending along the span thereof inboard of the opposite wing ailerons A, these longitudinal control surfaces L' being hinged to the fixed portion of the wings forward thereof along the hinge lines 21'.

The longitudinal control surfaces L' of Fig. 8 are actuated by generally similar pilot operated mechanism such as that shown and described in connection with Fig. 7, which mechanism includes the bell crank 39 connected with the control stick by the link 40 and with the opposite wing mounted bell cranks 37 and 38, respectively, by the push-pull rods 39a and 39b. Bell crank 37 of wing RW is connected with the longitudinal control surface L' by the link 37c and the bell crank 38 of the wing LW is connected with the longitudinal control surface L' of that wing by the link 38c. Thus, forward movement of the control stick C simultaneously lowers longitudinal control surface L' while rearward movement of the control stick C simultaneously raises the longitudinal control surfaces.

The feature of the form and arrangement of Fig. 8 resides in the utilization of the opposite wing ailerons A as the adverse lift neutralizing surfaces for displacement and adjustment by the pilot independently of the longitudinal control actuation of the surfaces L' , and further, without interfering with the pilot actuation of these opposite wing ailerons A as roll control surfaces. In carrying out this feature, the rotatable hollow shaft 22 having the opposite rods 23 and 24 oppositely threaded axially into opposite ends thereof, as explained in connection with Fig. 7, is utilized, but, this shaft is not only rotatably mounted in its bearings 22b but is also axially movable or slidable through these bearings. The shaft 22

is rotated by the sprocket and chain mechanism including the hand operating crank 30 of Fig. 7, but due to the fact that the shaft has axial movement bodily through its bearings 22b, the sprocket 32 is splined or keyed onto the shaft 22 by means of a key 32a so as to permit axial movement or sliding of the shaft 22 through the sprocket 32 while providing for rotation of the shaft 22 by rotation of the sprocket.

The simultaneous vertical displacement in the same direction for adverse lift neutralizing function of the opposite ailerons or roll control surfaces A, is carried out by rotating the shaft 22 from the hand crank 30, in a direction to either draw rods 23 and 24 inwardly or force them outwardly. Rod 23 is coupled by the push-pull rod 15 with a right-hand wing aileron A through the bell crank 17 and link 17a, while the rod 24 is coupled with the aileron A of wing LW through the push-pull rod 16, through the bell crank 18 and the link 18a.

The differential displacement of the opposite ailerons A for roll control has been hereinbefore generally referred to and is carried out independently of the operation of ailerons A as adverse lift neutralizing surfaces through the medium of the push-pull rods 15 and 16 and the shaft 22. In the particular example hereof, the torque tube shaft 14 which is rockable or rotatable by lateral movement of the control stick C through the linkage 41, extends to a point disposed transversely of but adjacent shaft 22 and carries a yoke 42 through which shaft 22 extends. A sleeve 43 is rotatably mounted on shaft 22 and confined between the opposite end collars 44 fixed to shaft 22. This sleeve 43 carries the diametrically opposite outwardly extending studs 45 which are pivotally received in slots in the opposite upwardly extended arms of yoke 42. Thus, shaft 22 is free to rotate in sleeve 43 and is axially or longitudinally movable by rocking yoke 42.

Lateral control actuation of the opposite ailerons A is thus carried out by rocking control stick C which rocks the torque tube 14 and in turn rocks yoke 42 to axially move shaft 22 in one direction or the other to vertically displace the opposite ailerons A in opposite directions through the push-pull tubes 15 and 16. The axial movement of shaft 22 is carried out by sliding this shaft in its bearings 22b and through the sprocket 32 keyed to the shaft.

In another form of longitudinal control of the invention, the longitudinal control surfaces and the adverse lift neutralizing surfaces are simultaneously and coincidentally but differentially operated throughout the control range from a common control, which, in the example hereof, is provided by the pilot's control stick C. A possible arrangement of mechanism for carrying out such coincidental and differential operation of the longitudinal control and the neutralizing surfaces, is illustrated by Fig. 9 of the drawings when considered in connection with Fig. 7.

The arrangement of the system and mechanism of Fig. 9 provides for fore and aft or forward and rear swinging of the control stick C, rotating a shaft 46 which carries a relatively large sprocket or gear 47 operatively connected with a relatively small sprocket or gear 48 mounted on the shaft 29 by a chain 49. The ratio between sprocket or gear 47 on shaft 46 and the sprocket or gear 48 on shaft 29 is relatively large, so that a small degree of rotation of sprocket or gear 47 will result in considerably greater rotation of sprocket or gear 48 on the shaft 29.

Rotation of the shaft 29 through the above arrangement of gearing rotates the shaft 22 to simultaneously raise or lower the neutralizing surfaces V, referring now to Fig. 7 of the drawings, and as this lowering or raising of surfaces V is caused by rearward or forward movements of the control stick C, there is coincidental and simultaneous upward or downward displacement of the longitudinal control surfaces L respectively.

The cranks and connecting links and their relative angular displacements in the longitudinal control operating mechanism are so arranged that upon fore and aft movements of the control stick C, the neutralizing surfaces V will be displaced in the direction opposite to the direction of displacement of the control surfaces L and at varying angles of displacement relative to the angles of displacement of the surfaces L throughout the range of control displacement of these latter surfaces. This differential or varying angle ratio is such that the required neutralizing effect of surface V is obtained in accordance with the angle of attack of the wings or lifting surfaces and the direction of displacement of the longitudinal control surfaces, that is, whether this displacement is to a positive or negative angle position relative to the lifting surfaces or wings.

With the simultaneous, coincidental and differential actuation of the longitudinal control surfaces L and the neutralizing surfaces V from a common control point, it is essential that there be included some form of irreversible operating mechanism between the neutralizing surfaces V and the pilot's control, such as the control stick C, and in the example hereof, the irreversible mechanism is provided by the threaded rods 23 and 24 engaged in the threaded shaft 22, through the medium of which the displacement of the neutralizing surfaces is obtained.

It is to be further noted that a preferred feature of any arrangement of mechanism for carrying out the coincidental and differential operation of the longitudinal control and adverse lift neutralizing surfaces is to arrange such mechanism, as in the example of Fig. 9, taken with Fig. 7, so that the longitudinal control surfaces are directly coupled to the pilot's control member, such as the stick C, rather than coupled mechanically through the irreversible mechanism in the operating system for the neutralizing surfaces, in order to obtain normal control stick force loads as to magnitude and direction. I have determined that while under certain conditions it may be desirable to operate the longitudinal control surfaces and the neutralizing surfaces coincidentally, the forces acting on the pilot's controls are reversed and it is practically necessary and essential to provide some means to either relieve the load entirely as by an irreversible control mechanism, or by the introduction of some other form of mechanism and/or aerodynamic means for reversing these forces on the pilot's control. This condition is therefore remedied by the foregoing feature of my invention as typified by the example of an arrangement of Fig. 9 utilizing the irreversible mechanism.

The invention also includes in combination with the longitudinal control surfaces of a tailless airplane, the use of aerodynamic means or members in the form of trailing surfaces or tabs mounted on a control surface and angularly vertically adjustable relative thereto. For instance,

in Fig. 1 of the drawings, I have shown trailing surfaces or trimming tabs 1 adjustably mounted on the trailing portion of each control surface L and vertically angularly adjustable relative to the control surface on which mounted. Similar tabs are to be used with longitudinal control surfaces L' of Fig. 8, if desired.

Longitudinal control of the tailless type of airplane such as provided by a design of the present example may be obtained by the use of wing-mounted, vertically disposed surfaces which are laterally displaceable, instead of by the use of the horizontal or elevator type of control surfaces L or L' hereinbefore described. For example, in Fig. 20 of the drawings, I have more or less diagrammatically disclosed a longitudinal control system arrangement embodying such vertical laterally displaceable longitudinal control surfaces mounted on the opposite wings adjacent the respective wing tips above and below the wing for simultaneous, lateral displacement of the surfaces above the wing to develop stalling moments, or simultaneous lateral displacement of the surfaces below the wing, to develop diving moments.

In the arrangement of Fig. 20, a vertical longitudinal control surface L² is mounted on the lifting surface at the upper side thereof adjacent each tip of such lifting surface or wing and these opposite wing tip surfaces L² are laterally swingable about vertically disposed axes. Suitable operating mechanism connects these two control surfaces with the pilot's control stick, such as the control stick C, so that these surfaces are simultaneously laterally displaced in opposite directions when the control stick is moved rearwardly from its neutral control position, but remain inactive when the control stick is moved forward from its neutral control position. This lateral displacement of these opposite wing tip vertical surfaces develops stalling moments for longitudinal control.

A generally similar pair of vertically disposed laterally displaceable longitudinal control surfaces L₃ are mounted on the lift surface or opposite wings adjacent the tips thereof, respectively, but at the under side of the lifting surface with the surfaces L² depending or extending downwardly therebelow and mounted for lateral displacement. Suitable operating mechanism is provided coupling these lower longitudinal control surfaces L³ with the pilot's control stick, in such a manner that forward movement of the control stick from its normal neutral control position will simultaneously laterally displace the surfaces L³ in opposite directions to develop diving moments for longitudinally controlling the airplane. The operating mechanism for the lower longitudinal control surfaces L³ is so arranged that upon rearward movements of the control stick C from its normal neutral control position, the longitudinal control surfaces L³ remain inactive and in their neutral positions.

As an example, an operating mechanism for the upper longitudinal control surfaces L² may embody a cable 96 connected to the lower end of the control stick C below the axis of fore and aft swing of the stick, which cable is coupled to branch cables 96a and 96b extending over suitable pulleys outwardly along opposite wings, respectively to the operating arms 96c and 96d of the opposite vertical control surfaces L². A cable slack take up unit M is included in the cable system between the cable 96 and the branch cables 96a and 96b. Thus, rearward swinging

of the control stick C will draw cable 96 forward and simultaneously laterally displace the upper longitudinal control surfaces L^2 . Suitable trailing edge tabs 96e may be employed for returning the surfaces L^2 to their normal neutral control positions upon release of the operating cables by forward movement of the control stick C, or, the surfaces may be spring loaded for return movement thereof upon release.

The lower vertical longitudinal control surfaces L^3 are actuated by forward movement of the control stick C through a cable 97 connected to the control stick above its axis of longitudinal swing, which cable is connected through the slack take up unit M with the branch cables 97a and 97b extending around suitable pulleys outwardly through the opposite wings to the control surface operating arms 97c and 97d, respectively, of the opposite surfaces L^3 . Thus, forward movements of the control stick C draw cable 97 forwardly, and through cables 97a and 97b, the lower vertical surfaces L^3 are simultaneously displaced laterally to develop diving moments for longitudinal control. The vertical longitudinal control surfaces L^3 may be returned upon release to their normal neutral control positions by trailing edge tabs such as 96e or they may be spring loaded by a spring such as indicated at 98 on the right-hand control surface. Such a return spring may be connected with the control surface operating arm or in any other suitable manner. Preferably, suitable stops are provided (not shown) such as those provided for the vertical and laterally displaceable surfaces R or D of Figs. 10 and 11.

The cable slack take up units M in the cable systems functions to eliminate slack in that system remaining inactive when the other system is operated for control.

Such an arrangement of vertical wing mounted and laterally displaceable surfaces may be employed alone as the sole longitudinal control for the airplane, or, may be utilized together with the longitudinal control forms of Figs. 7 and 8 in which vertically displaceable horizontal surfaces, such as L and L' are employed so that these vertical types of longitudinal control surfaces augment the longitudinal control moments developed by control surfaces such as L and L' .

Similarly, these vertical laterally displaceable forms of longitudinal control surfaces may, in accordance with my invention, be used in cooperation with longitudinal control surfaces of the type of L or L' , in arrangements by which either the vertical longitudinal surfaces L^2 above the wing are alone utilized, or, vertically laterally displaceable longitudinal control surfaces L^3 below the wing are alone used.

In the operating or use technique, the vertical or laterally displaceable surfaces L^2 and L^3 may be employed for developing the pitching moments while control surfaces of the horizontally disposed vertically displaceable type such as L, or such as the ailerons A, may be employed as adverse force neutralizing surfaces. In the operation of these vertical types of longitudinal control surfaces L^2 and L^3 , adverse forces are set up by their operation, of the same general character as discussed in connection with the adverse lift developed by the horizontal vertically displaceable types of control surfaces, so that the invention recognizes such conditions and includes with the vertical types the use of an adverse force or lift neutralizing surface or surfaces.

While I recognize that the wing tip location is

the most efficacious, my invention is not limited or restricted to such location but includes various locations spanwise of the wing. As an example of the approximately extreme inboard location of such surfaces, reference is made to the air brake surfaces D of Fig. 11, and to the fact that such surfaces so located develop a pitching moment.

Control synchronizing

As shown in dotted outline in Fig. 1 of the drawings, the space or gap between the vertically angularly displaceable types of control surfaces such as the control surfaces L, V and A, may be closed against pressure leakage by applying suitable sealing means, such as the tapes or flexible sealing strips 95, to close the passage. Sealing of the gap between these surfaces increases the effectiveness of the controls, and in accordance with my invention, varying the degree to which the gaps are sealed is varied so as to result in a synchronizing of the control reaction on the pilot, so that, the movement of the control member actuated by the pilot is in the proper proportion with regard to both the magnitude of the force and the angular displacement of the control member, in this way synchronizing the control reaction on the pilot.

Directional or yaw control

The directional or yaw control for the tailless airplane of my design is in this instance provided by vertical rudders R mounted at the upper sides of the wings RW and LW adjacent the wing tips, respectively, and located on the rear or trailing portions of the wings.

Referring now to Fig. 10 of the drawings in particular, each rudder R is rotatably mounted upon shaft 50 on the wing adjacent the wing tip and so located that the trailing edge of the upwardly extending rudder R terminates substantially at or but a relatively short distance to the rear of the trailing edge of the wing tip structure. In normal neutral control position, each rudder R is disposed at substantially a ninety degree (90°) angular position relative to the major longitudinal axis of the wing and is moved for directional or yaw control about the axis provided by the shaft 50 by displacing the rudder outwardly so that it assumes the dotted line position of the rudder R on wing RW of Fig. 10.

The operating control mechanism for each rudder R includes the outwardly extended horizontally disposed lever arm 51 in fixed relation to a rudder R for swinging therewith, and this arm, in the normal neutral control position of a rudder R is engaged against a stop member 52. A spring 53 is connected between the free end of each rudder actuating arm 51 and a fixed point in the wing structure to the rear of the arm so that in each instance such spring 53 normally draws and holds the arm 51 swung rearwardly against the stop 52 to maintain the rudder R in its normal neutral control position.

The pilot's control mechanism for operating the opposite wing tip rudders R provides for selective actuation of either rudder alone in accordance with the yaw control principles of my invention, and in the present instance, embodies a pair of foot pedals 54 and 55 located in suitable position for pilot actuation. These pedals 54 and 55 are mounted and fixed upon concentric shafts 56 and 57 with the shaft 56 extending into and rotatably received by shaft 57 so that there may be relative rotational movement of

these shafts. It so happens that in the present example, I have shown a possible dual control pedal arrangement for side by side seats, such arrangement including the pair of pedals 54' and 55' with pedal 54' carried by shaft 56 and pedal 55' by shaft 57. The pedal 54' of shaft 56 extends through a slot or opening provided in the shaft 57 to permit movement of this pedal for rotation of shaft 56 independently of and without interfering with the shaft 57, as will be clear by reference to Fig. 10 or to Fig. 12.

An arm 58 fixed on shaft 56 is connected by an operating cable 59 with the outer free end of the crank arm 51 of the left rudder on the wing LW and an arm 60 is fixed on the shaft 57 and is connected with the outer free end of the crank arm 51 of the right rudder on wing RW by an operating cable 61. The operating cables 59 and 61 extend over and around suitable pulleys to guide and maintain these cables in operative position between and connecting their respective pedal shafts with the rudder crank arms.

A cable slack take up unit M is connected in and forms a part of each of the cables 59 and 61, respectively, the construction and arrangement of such a slack take up unit being disclosed in Fig. 17 of the drawings to which reference will now be made. The unit M, for example, embodies a cylindrical casing 62 carrying a plunger 62a mounted for longitudinal reciprocation within the cylinder and extending outwardly through one end of the cylinder for connection to the cable in which the unit is mounted. The opposite end of the casing 62 is adapted to be connected by any suitable coupling to an end of the cable in which the unit is utilized. A coil expansion spring 62b is interposed between the head of the plunger 62a and the shoulder or abutment structure 62c in the casing and the plunger carries a collar or stop 62d spaced a distance from the plunger head for engaging the abutment structure 62c to limit movement of the plunger in the casing in one direction. In normal position connected into an operating cable, the normal load in the cable maintains the coil spring under partial contraction so that upon removal of the load in the cable, the spring 62 expands further to force the plunger through the casing and draw the opposite sections of the cable in which the unit is mounted closer together and thus take up any slack in the cable.

With the arrangement of opposite wing tip rudders and the operating mechanism therefor, in the form of the present example, only one rudder is operated at a time to obtain directional or yaw control. For example, if it is desired to turn the airplane to the left, the left rudder R on wing LW is displaced by the pilot laterally outwardly, while the opposite right rudder R on wing RW remains in its normal neutral position. If it is desired to turn the airplane to the right, the right rudder R on wing RW is actuated by the pilot and the left rudder on wing LW remains in its normal neutral control position.

Outward displacement laterally of the left rudder R on wing LW in order to set up yawing moments acting in a direction to turn the airplane to the left, is accomplished by pushing the left pedal 54 (54') forwardly to rock shaft 56 and pull the cable 59 forwardly and thereby swing rudder R laterally outward against the tension of its spring 53. During this left rudder actuation, shaft 56 rotates independently of the shaft 57 and the right pedal 55 is moved in the

opposite direction through reversing unit N, with the resultant slack in cable 61 taken up by unit M, so that there is no actuation of the opposite right rudder R. Upon release of the forwardly rocked left pedal 54 by the pilot, the left rudder spring 53 returns that rudder to its normal neutral control position with the crank arm 51 engaged and held against the stop by the spring. Lateral outward displacement of the right rudder R on wing RW is accomplished by the pilot pushing or rocking the right pedal 55 forwardly which rocks shaft 57 and through arm 60 and cable 61, swings right rudder R laterally outwardly to control position against the tension of spring 53. Release of the right pedal 55 permits the spring 53 to return right rudder R to its normal neutral control position with its arm 51 held against the stop 52.

In place of or in conjunction with the rudder return spring 53, I may employ a form of aerodynamical means for returning a rudder to and holding it in neutral position against its stop, such for example as a suitable tab surface 63a mounted on the trailing edge of the rudder and angularly adjustable to establish the required force acting in the required direction to return and maintain the rudder to and at its neutral control position.

If desired or found expedient, a form of pedal shaft motion reversing mechanism of my invention may be employed for a steering control system of the type above described and as shown in Fig. 10 of the drawings. Such a reversing unit N is disclosed in operative position coupling shafts 56 and 57 in Fig. 10 of the drawings and is shown in detail by Figs. 5 and 6 of the drawings.

Referring now to Figs. 5 and 6, the unit N includes a suitable casing structure 63 in which is mounted a shaft 64 carrying the spaced opposite wheels or rollers 65 rotatably mounted thereon, with the rollers 65 confined in opposite tracks provided by the casing structure 63, so that this shaft and its supporting rollers are movable or slidable longitudinally back and forth within the casing structure 63. Casing structure 63 is provided with longitudinally disposed slots or openings in its upper and lower sides and a link 66 is mounted on shaft 64 intermediate the rollers 65 and extends forwardly therefrom to and is pivotally connected with an upwardly extending arm 67 fixed on the pedal shaft 57. A link 68 is mounted on and carried by the shaft 64 and this link 68 extends forwardly and downwardly to an arm 69 fixed on and carried by the pedal shaft 56.

Thus, the unit N operatively couples and connects the pedal shafts 56 and 57 carrying the right and left pedals, through the medium of the links 66 and 68 and the common shaft 64 bodily transversely movable back and forth in the casing structure 63. Hence, upon operation of a left pedal 54 (54') to actuate the left rudder with the forward rotation of the shaft 56, arm 69 on that shaft is rocked rearwardly and through link 68 slides or rolls shaft 64 in the unit N rearwardly in the casing structure 63. Rearward movement of shaft 64 pulls the link 66 rearwardly and rearwardly rotates the right pedal shaft 57, thus reversing the movement of that shaft and the right pedal 55 (55') carried by that shaft with respect to the forward control operating movement of the left pedal 54 (54'). Upon the control actuation of a right pedal 55 (55') to rotate shaft 57 forwardly, the unit N reverses

such motion and transmits it to shaft 56 as a rearward motion of that shaft and the left pedal 65 (54') carried by such shaft. Thus, a simultaneous operation of a pair of right and left pedals in the reverse directions is obtained. With such reverse movement of the opposite idle pedal to a control operated pedal, there is of course a slackening of the rudder operating cable connected to the idle pedal but the slack so resulting in a rudder operating cable is taken up by a slack take-up unit N connected in the cable.

A rod or the like 64a is connected through the common shaft 64 and is reciprocated by movements of the shaft longitudinally in the casing. This reciprocating rod 64a may be extended through any suitable mechanism for steering actuation of the link rod 85 of the wheel steering mechanism of Fig. 12, or may be utilized for actuating the rudder operating cables or rods of the rudder control mechanism of Fig. 10.

It is to be particularly noted that the opposite wing tip rudders R providing the directional or yaw control in accordance with my invention, have no associated fixed vertical fin area forming portions of the directional control surfaces. In normal neutral control positions held by the springs 53 or tabs 53a, the opposite wing tip rudders R function as vertical fins and, upon directional control operation of either of these rudders, the opposite rudder is not actuated but remains in its normal neutral control position and continues to function as vertical fin area. In connection with the opposite wing tip rudders R of the invention, a feature thereof resides in utilizing for each rudder a surface having a cambered section in which the cambered side, or side of greatest camber, is on the inner side of the rudder, as will be clear by reference to Fig. 1 of the drawings. Such arrangement which provides the rudder surfaces with their inboard sides cambered obtains an increase in control moment due to the rearward location of the center of pressure on a surface of this kind at small angles, of lateral displacement. In the directional control operation of the opposite wing tip rudders R so designed, mounted and arranged, the displacement of a rudder R results primarily in establishing drag as well as a stalling moment at its wing tip.

The opposite vertical laterally displaceable rudder forming surfaces R may, if desired, be used for simultaneous outward or inward displacement for the purpose of creating drag so that these wing tip surfaces may then be utilized as air brakes or surfaces for creating a stalling moment, and my invention includes the operation and use of such wing tip surfaces for this purpose to carry out such air brake or stalling function. Any suitable mechanism may be employed for simultaneously outwardly or inwardly swinging these surfaces, such, for example, as the mechanism shown in Fig. 11 of the drawings and described hereinafter.

While in the preferred form, the rudders R are located at the upper side of the wings, my invention recognizes and includes locations of the rudders both above and below the wings, such as described in connection with the use of such vertical surfaces for longitudinal control.

It is recognized that under certain design conditions, a relatively large cross-wind force is introduced when the rudders are turned outboard, and that this cross wind force may be detrimental to the directional control of the aircraft. Therefore, my present invention contem-

plates and includes that under such conditions, the tip rudders may be interconnected with the air brakes or drag establishing surfaces so as to neutralize this cross wind force, or, as another alternative, that the tip rudders may be turned inboard in order to reverse the direction of the cross wind force. My invention further includes in its treatment of this condition, the use of multi-plane tip rudders actuated in opposite directions for the purpose of neutralizing the cross wind force.

A feature of the invention is based upon the fact that in aircraft that have small directional stability, as in the case of the tailless types, the dihedral angle of the wing has a material effect upon the directional stability, and that where the dihedral angle is small, the directional stability of the complete aircraft is thereby improved, and that where the dihedral angle is large, the directional stability at increasing angles of attack will be lessened and may, in fact, result in instability under certain conditions. Therefore, in accordance with a feature of my present invention, the dihedral angle of the wing is maintained at approximately zero degrees.

Two control

A further characteristic of the invention recognizes that a directional or yaw control is possible in a tailless design of my type by the elimination of the movement of the vertical surfaces. A substitution for this movement is obtained by displacing the aileron or roll control surfaces to establish drag at their respective wing tips, thus causing a change in direction as well as introducing their primary function of roll control. This dual function requires that the ailerons themselves be readjusted in relation to their angle of trail to the fixed portion of the wing. By this adjustment, the adverse drag is eliminated or reduced to a degree that permits the directional or yaw control of the airplane.

In accordance with another feature and form of two-control arrangement, the invention provides the elimination of the movement of the ailerons or roll control surfaces A, and obtains roll control by the differential operation of the yaw control surfaces or rudders R, in the form of Fig. 10. Thus, two controls embodying the pitch control by surfaces L or L' and roll and yaw control by rudders R, may be provided.

Air brakes

The development of drag for the purpose of braking or retarding forward movement of the airplane forms a phase of my present invention and I have disclosed herein an arrangement of movable surfaces for developing drag for braking purposes, and in addition, I have so located and arranged these surfaces relative to the body B of the airplane and the propeller P that a beneficial cooperation with the airflow past the body and to the propeller P is obtained.

Referring now particularly to Figs. 1 and 2 of the drawings, I have shown a possible embodiment of drag establishing surfaces D in the form of vertical surfaces mounted at the upper side of the trailing portion of the lifting surface at opposite sides of the rear or trailing portion of the body B. In the specific example hereof, these surfaces are mounted at the trailing portions of the opposite wing root forming portions LW' and RW' of the center section of the lifting surface, and are located spaced equidistant from the longitudinal axis of the body B and from each other

a distance slightly less than the propeller diameter, so that these opposite surfaces are disposed approximately forward of and substantially in line with the path of rotation of the propeller tips, as clearly shown by Figs. 1 and 2 of the drawings.

Each of these drag establishing vertical surfaces D is formed of a cambered section having the side thereof of greatest camber inboard and facing the body B, and the surfaces so formed are preferably maintained in their normal inactive positions as braking surfaces, displaced laterally inwardly toward each other, in this instance, at an angle of approximately three degree (3°), so that the surfaces are disposed in directions substantially following the general rearward contour and airflow direction at the adjacent sides, respectively, of the body B. The positioning of these surfaces forward of the propeller and adjacent to the propeller tips of an inward angular displacement tends to conform to the airflow into the propeller so that these surfaces act as guide vanes and maintain a more uniform flow of air to the propeller, thus improving its efficiency and preventing to a degree tip flutter on the propeller blades thereby reducing the noise resulting from such flutter. It is recognized that the present design covers only a relatively small area of the propeller stream but under other design conditions where the proportionate diameter of the propeller blade is smaller in relation to the overall dimensions of the airplane, additional surfaces may be provided so as to include an almost complete shrouding of the propeller with a corresponding improvement in efficiency and a reduction in propeller noise. This feature of my invention in its basic aspect is not concerned with whether the shrouding surface is a displaceable surface or a fixed surface and includes a normally fixed but adjustable surface or surfaces with the camber, if any, inboard or outboard and at a positive or negative angle, before or behind, or in the plane of the propeller, or within or without the disk area of the propeller.

The braking surfaces D are mounted on the lifting surface for lateral displacement about substantially vertical axes for simultaneous movement inwardly or outwardly to drag establishing, braking position.

Any suitable mechanism may be employed for operating these braking surfaces, and in Fig. 11 of the drawings, one possible form of such operating mechanism is disclosed. For example, the right-hand surface D is provided with an outwardly extended arm 69a mounted thereon for movement with the surface D and the outer end of this arm is connected to a contracting spring 69b which extends rearwardly from the arm and is secured at its opposite end to fixed structure of the lifting surface. The spring 69b continuously tends to swing such arm rearwardly and displace or rotate the right-hand surface D inwardly. A stop 69c is provided which engages an arm 69d extending rearwardly from and fixed for movement with surface D, so that the surface D is normally maintained by the spring 69b held in normal inactive position by arm 69d engaged against the stop 69c.

The left-hand braking surface D has a forwardly extending arm 70a mounted for movement therewith and engaging a stop 70b to maintain the surface D in its slightly inwardly displaced normal inactive position such as shown in Fig. 1. A spring 69b is employed for maintaining arm 70a against stop 70b. The forward

end of arm 70a is connected with the rear free end of the arm 69d by a cable connection 71 which may include a suitable turnbuckle or the like 71a.

A pilot actuated hand-pull lever 72 is mounted at a suitable location in the body B accessible to the pilot for actuation to simultaneously outwardly displace the drag establishing brake surfaces D and to release these surfaces for return to their normal inactive positions. This lever 72 is operatively connected by means of a cable 73, in this instance, with the outer end of arm 69a of the right-hand surface D. The cable 73 is mounted over and around a series of pulleys 73a in such a manner that upon pulling the hand lever 72 rearwardly, the cable swings arm 69a forwardly and thus laterally displaces right-hand surface D outwardly, which in turn, through the connecting member 71 simultaneously outwardly displaces the left-hand surface D. Upon release of the hand lever 72, the spring-loaded surfaces D are returned to their normal inwardly displaced inactive positions maintained against the stops 69c and 70b. Hand pull lever 72 is provided with a suitable ratchet mechanism 72a for releasably holding the handle in an adjusted or outwardly drawn position with the surfaces D outwardly displaced into drag establishing and air braking positions. In place of or in conjunction with a spring 69b of an air brake surface D, I may employ an aerodynamical means for returning a surface D to and holding it in normal neutral position against its stop, such for example as a suitable tab surface 69e mounted on the trailing edge of a surface D and angularly adjustable to establish the required force acting in the required direction to return and maintain the surface to and at its neutral position.

Landing gear

The principles embodied in the general landing gear design and arrangement hereof, form an important feature of the invention of general adaptability to airplanes both of the tailless and the tailed types, but of particular value in overcoming the conditions hereinbefore set forth as encountered and inherent in the truly tailless type of airplane of a design of my present invention. According to these principles, the landing gear has its forward wheels and the rear landing wheel or wheels spaced forward and to the rear, respectively, of and approximately the same distance from the center of gravity, with the rear wheel or wheels located within the projected plan or area of the lifting surface and the forward wheels located spaced but a relatively short distance forward of the leading edge of the lifting surface.

For instance, in the particular embodiment of the landing gear of the present example, this gear is of the three-wheel type, although the invention is in no sense so limited, and has the forward wheels 11 spaced apart laterally and located at opposite sides of the body B to provide a relatively wide tread, and the rear wheel 10 located in the vertical plane of the longitudinal axis of the body and beneath and within the projected area of the lifting surface. Referring particularly to Fig. 13, the forward wheels 11 and rear wheel 10 are located spaced forwardly and rearwardly, respectively, substantially the same distance from the center of gravity, so that the weight load of the airplane, when normally at rest on the ground, is substantially equally dis-

tributed between the forward and rear wheels. In the airplane of the present example, the center of gravity location is indicated in Fig. 13 and the permissible range of movement fore and aft of the location of the center of gravity is schematically indicated by the shaded area in Fig. 13. With the inherently stable wings of the type used in this instance, the range of center of gravity location is approximately fifteen per cent (15%) to twenty-one per cent (21%) of the mean aerodynamic chord of the wing. With such center of gravity location, the forward and rear wheels are so located that a plane passing through the axes of the forward wheels 11 and extending rearwardly and upwardly through the center of gravity has an angle of approximately forty-five (45) degrees to the vertical, while a plane passing through the axle of the rear wheel 10 and extending upwardly and forwardly through the center of gravity also has an angle to the vertical of approximately forty-five degrees (45°), so that the included angle between the forward and rear wheels and the center of gravity is approximately ninety degrees (90°), in the specific example hereof.

The rear wheel 10 is mounted for lateral swinging or rotation for steering, but is normally maintained directionally fixed, and, referring to Fig. 13, is located within the rear housing or fairing H that depends from the body B and is mounted and carried at the lower end of a suitable strut or leg 74 which carries and provides at its upper end a cylinder 74c. A plunger or piston 74b is suitably pivotally mounted on the body B and extends downwardly therefrom and is confined in the cylinder 74a for reciprocation therein through a suitable body of oil or other fluid—all in accordance with usual hydraulic shock absorbing unit practice. A spring or the like 75 is connected between the lower portion of the housing structure H and the upper portion of the shock absorber cylinder 74a carried by the wheel 10. Thus, with the airplane at rest on the ground and the wheel 10 supporting a portion of the weight thereof, the plunger or piston 74b is in substantially the position shown in Fig. 13, while with the airplane in the air and the weight loads removed from wheel 10, this wheel, with its mounting including the cylinder 74a, lowers, aided by the force of the spring 75, to the dotted line position of wheel 10 shown in Fig. 13, with the cylinder 74a lowered and the plunger 74b located in the upper portion of such piston above the body of oil therein. Preferably, the mounting of the rear wheel 10 provides for some movement of the wheel and its absorbing unit longitudinally or fore and aft of the body, but, the wheel is normally held against rotation laterally, that is, is directionally fixed.

The spaced forward landing wheels 11 are mounted upon and carried by the upwardly and inwardly inclined struts or legs 76, referring now particularly to Figs. 12 and 18. These struts or legs may be, as in the present instance, suitably trussed or braced at their under sides as by the vertically disposed longitudinal trussing flange 76a. Each wheel strut or leg 76 is mounted for vertical rocking on and about a horizontal axis disposed longitudinally of the body B, and such axis may be provided by a shaft 77 fixed to and extending across the strut or leg intermediate the upper and lower ends thereof and mounted in suitable opposite end bearings 77a (see Fig. 12) carried by the body B, in a lower side thereof. So mounted and arranged, the opposite wheel

legs or struts 76 are vertically rockable or swingable about axes formed by the shafts 77 with the inner ends of the legs or struts extended inwardly a distance through the body to the central portion thereof.

The inner ends of wheel legs or struts 76 are spaced apart and each is provided with a transversely disposed pin providing the opposite side studs 78.

A feature of the landing gear of the invention embodies the provision and use of a common shock absorbing unit centrally located within the body B intermediate the opposite wheel legs or struts for operative coupling and association with said struts at the strut inner ends. Referring now particularly to Figs. 18 and 19 of the drawings, such a shock absorbing unit may embody a hydraulic cylinder 79 mounted centrally of the body B beneath and intermediate the inner ends of the opposite leg struts 76, which cylinder 79 is charged with or contains the usual body of oil or other shock absorbing medium. This cylinder of the shock absorbing unit is mounted and carried upon a triangular truss structure 80 which extends between the cylinder and the opposite leg or strut bearings 77a, which bearings are mounted on and carried by such truss.

A piston or plunger 81 is confined in cylinder 79 for vertical reciprocation therein through the body of oil or fluid in the cylinder and this piston or plunger has an upwardly extending piston rod 81a slidably confined in and extending upwardly through a suitable bearing in the upper end of the cylinder. At the upper end of the piston rod 81, there is mounted and fixed a horizontally disposed cross-head unit 82. This cross-head includes (see Fig. 12) the parallel side members each having a longitudinal slot or slots 82a therein and the studs 78 at the upper inner ends of the opposite wheel legs or struts 76 which are slidably received and confined in the slots 82a between the opposite ends, respectively, of the spaced side members of the cross-head 82. By this arrangement and operative connection of the inner ends of the opposite wheel struts to the cross-head 82, these wheel legs or struts are simultaneously vertically rockable or swingable to raise and lower the plunger 81 in the cylinder 79 of the shock absorbing unit and it will be apparent that vertical displacement of one leg or strut is positively accompanied by corresponding vertical displacement of the opposite leg or strut so that the airplane tends to always maintain its normal horizontal attitude laterally. The upwardly displaced position of the landing wheels 11 and the downwardly displaced position of plunger 81, when the airplane is in normal position on the ground with the landing wheels supporting the weight of the airplane, is shown by Fig. 19.

The front wheels 11 of the landing gear are mounted on and carried by the outer ends of the opposite struts or legs 76, and, in accordance with the example of landing gear of my invention here shown, these front landing wheels are mounted for lateral swinging about approximately vertically disposed axes. Such a mounting for the wheels 11 may be of a more or less conventional type for steerably mounting wheels to an axle structure, and, as here shown, embodies a vertically disposed yoke 11a fixed at the outer end of each strut or leg 76a and rotatably receiving and mounting a vertically disposed member 11b, which member carries the axle 11c on which a

wheel 11 is mounted. Such an arrangement provides the more or less conventional type of steering knuckle mounting for a wheel member, but, in accordance with a further feature of my invention, these mountings for the front wheels 11 are such as to provide by means of the members 11b, vertically disposed axes so arranged that the front wheels 11 will inherently or automatically caster when the landing gear is in normal ground engagement and moving forwardly, due to the cooperation of these laterally swingable and casterable front wheels forward of the center of gravity, with the directionally stable rear wheel or wheels to the rear of the center of gravity.

The landing gear embodying the directionally fixed rear wheel 10, or rear wheels if desired, with the castering front or forward wheels 11, will automatically or inherently function upon ground contact in landing to cause the airplane to assume and follow the direction of landing rather than the direction of heading of the airplane. Similarly, when moving forward on the ground, this inherent directional stability will maintain the airplane on its course.

A suitable housing or fairing 83, referring now to Fig. 18 of the drawings, is provided enclosing that portion of each front wheel strut or leg 76 that extends outwardly from body B and such housing is fixed on and carried by the strut or leg 76 by members 83a, and extends to and terminates adjacent the wheel 11 mounted on such strut. A slidable and flexible connection 83b is provided between the fixed housing 83 and the side of the body B.

No claim is herein made to the inventions embodied in the design, arrangement, mounting and construction of the landing gear disclosed and described herein, as such inventions are disclosed and claimed in my pending U. S. patent application, Ser. No. 613,496, filed August 30, 1945.

With respect to the design, arrangement and construction of the common shock absorbing unit and the simultaneously vertically displaceable wheel legs or struts carrying the spaced forward landing wheels 11, no claim is made herein to the inventions embodied in such design, construction and arrangement, as such inventions are disclosed and claimed in my pending U. S. patent application, Ser. No. 613,498, filed August 30, 1945.

Ground steering of the airplane

The landing gear of the invention, as hereinbefore described, provides for steering the airplane on the ground by arbitrary directional control of the laterally swingable castering front wheels 11. The invention also includes pilot controlled means for directionally swinging the normally directionally fixed rear wheel 10 for ground steering and handling of the airplane, together with mechanism for releasably locking the rear wheel in directionally fixed location for take off and landing.

A possible form of pilot operated front wheel steering mechanism is disclosed in Figs. 12 and 18 of the drawings and embodies a series of cranks and links mounted on each front wheel leg or strut 76 in operative connection with a front wheel for laterally swinging or steering such wheel.

In the example hereof, each front wheel mounting includes a forwardly extended arm 84 fixed to and extending from the spindle 11b, and a link 84a couples the forward free end of this arm with an arm of a bell crank 84b mounted on and carried by the leg or strut 76 at the forward

side thereof. The fixed bearing structure 77a for the forward end of the strut shaft or axle 77 carries a U-shaped crank member 84c mounted for rocking movement on an axis substantially on the strut shaft 77. The outer arm of this crank member 84c is connected by a link 84d with an arm of the bell crank 84b. The crank 84c of the wheel steering mechanism on each wheel strut or leg 76 has the inner arm thereof coupled to one end of an operating rod 85 which is disposed transversely of and across the longitudinal axis of the airplane and connects the opposite crank members 84c in the opposite direction.

Actuation of the rod 85 for steering the opposite front wheels 11 is carried out by a suitable pilot actuated steering control mechanism, which, in the present instance includes the operating pedal unit for the directional control of the airplane. For instance, referring to Fig. 12, the arm 58 of the pedal shaft 56 may have an operating cable 85a connected thereto, while the arm 60 of the pedal shaft 57 may have an operating cable 85b connected thereto. These cables from the left and right-hand pedal mechanism are extended rearwardly over suitable pulleys or the like 85c and are connected at their rear ends to a coupling member 85d fixed to operating rod 85 intermediate the connection of the opposite ends of this rod with the opposite crank members 84c.

A releasable locking mechanism for holding rear wheel or wheels 10 in directionally fixed position for takeoff and landing, is more or less schematically illustrated in Fig. 13 of the drawings as including an apertured lug 74d fixed for lateral swing with rotation of wheel strut 74, and a fixed lug 74e thereabove having an aperture for vertical alinement with the aperture of lug 74d. A locking pin 74f removably extends downwardly through lugs 74e and 74d to hold wheel 10 in its normal directionally fixed position. A pilot operated means is provided for removing pin 74f from wheel locking position, and may consist of a cable 74g coupled to the pin and extending upwardly therefrom over suitable pulleys and forwardly to an operating hand lever mechanism 74h. Pin 74f may thus be raised and lowered to and from rear wheel locking position to release wheel 10 for steering or to hold the wheel in directionally fixed position.

The rear wheel 10 when released for lateral swing may be steered by and from the pilot operated front wheel steering mechanism, as for example, by cables 74i and 74k connected to the steering cables 85a and 85b, respectively, as shown in Fig. 12 of the drawings. Cables 74i and 74k are extended rearwardly to rear wheel strut 74 and suitably connected thereto for swinging wheel 10 in the proper direction relative to the direction in which front wheels 11 are steered. Suitable yielding means are preferably provided in the cables 74i and 74k to permit operation of the front wheel steering mechanism and the yaw control surfaces, when the rear wheel 10 is locked in directionally fixed position.

With the steering mechanism operated by and from the pedals for operating the directional air control of the airplane, when the airplane is on the ground and it is desired to turn to the left, the pilot pushes the left pedal 54 (54') forwardly to rock shaft 56 forwardly, and through cable 85a to move the rod 85 to the left. This rocks the outer arm of crank member 84c on the left hand wheel strut outwardly and downwardly, which laterally swings or turns the left-hand wheel outwardly and to the left. Simultaneously, through

the described operating mechanism, the right-hand wheel 11 is swung inwardly and to the left as the crank member 84c of the right-hand wheel steering mechanism is rocked inwardly. To steer the airplane to the right, the right pedal 55 (55') is pushed forwardly to rotate shaft 57 forwardly so that the opposite front wheels are swung laterally to the right.

No claim is herein made to the steerable features of the landing gear herein disclosed and described, as such steerable features are disclosed and included in claims of my pending U. S. patent application, Ser. No. 613,496, filed August 30, 1945.

Wheel brakes

Preferably, the forward and rear wheels 11 and 10 of the landing gear are provided with any desired type of brakes, and an arrangement of a possible brake operating system is disclosed herewith more or less diagrammatically in Fig. 13 of the drawings.

The illustrated system includes a brake applying lever 86 of the "pull" type mounted in the control cockpit of the body B accessible to the pilot and including suitable ratchet mechanism 86a to set the system in an adjusted brake applying position. This lever 86 is mounted to be pulled rearwardly for a brake application and to move forwardly to brake releasing position. Operating lever 86 is connected into and actuates a brake operating cable system that includes the cable 87 connected to the lever 86 and extending to and connected through another pilot operated brake applying hand lever 88 with a cable 87a, which is connected with cables 87b, respectively, only one of which is shown, operatively coupled with the opposite brakes of the front wheels 11. A cable 87c extends rearwardly through the body B over the spaced pulleys 87d and then downwardly to the operating arm 87e of the brake of rear wheel 10. The spaced pulleys 87d are located in the center line or radius of motion of the radius rod 74c that pivotally connects rear wheel 10 mounting 74 with the body B. Similarly, the pulleys such as 87f for the front wheel brake cables 87b are mounted and located on the center line or radius of motion of the vertical displacement of the front wheels 11.

The operating lever 88 for the brake system provides for service application of the brakes, while the lever 86 with its ratchet or rack and pawl mechanism 86a provides for brake application for parking.

The provision of brakes on all wheels of the landing gear, both front and rear, is made possible by the extreme forward position of and lateral locations of the two front wheels with reference to the center of gravity. While the art has pointed out the use of a forward brake on a three wheel landing gear with a single wheel forward, the braking effect of this wheel is definitely limited due to the possibility of danger of overturning the airplane on an axis between the single front wheel and a laterally spaced rear wheel.

No claim is herein made to the arrangement of wheel brakes on the forward and rear landing of a landing gear as herein disclosed and described, as such wheel brakes are disclosed and claimed in combination with a landing gear embodying the features hereinbefore disclosed, in my pending U. S. patent application, Ser. No. 613,496, filed August 30, 1945.

Take off

In carrying out that important feature of my invention by which certain problems and difficulties encountered in taking off a tailless airplane, as hereinbefore generally referred to and explained, are overcome, the landing gear embodying the forward and rear wheels located relative to the center of gravity so as to be spaced substantially equidistant forwardly and rearwardly therefrom and at approximately the same angles thereto in conjunction with the angle of incidence of the wing in ground-supported position of the airplane and the location of the line of thrust developed by the propeller P forms the basis of this feature of the invention.

Referring to Figs. 3 and 13 of the drawings, the airplane, in normal position supported on the ground has the body B substantially horizontally disposed and the lifting surface or wings are mounted normally in fixed relation thereto so that in the specific example hereof, the lifting surface is at an angle of incidence of approximately nine degrees (9°). As hereinbefore pointed out, with the tailless type of airplane having no aerodynamic elements located substantially to either the rear or forward of the lifting surface of the wing, and with a landing gear incorporating the desired characteristics, it is practically impossible to develop moments acting about the center of gravity for the purpose of changing the ground-supported attitude of the body and the lifting surface so as to increase the angle of attack of the lifting surface to such an angle that will permit take off.

In order to increase the angle of attack of the lifting surface or wings of the tailless airplane hereof, my invention utilizes the available forces acting about the center of gravity of the airplane and in relation to changes in center of gravity as the airplane takes off, in such a manner as to overcome the forces opposing raising of the forward portion of the body about the center of gravity in order to increase the angle of attack of the lifting surface. With the neutralization or reduction of such opposing forces, I then apply an additional mechanical force acting about the center of gravity of the airplane in order to raise the forward portion about the center of gravity and thereby increase the angle of attack for take off. This feature of the invention is characterized particularly by the arrangement which provides for fully automatically carrying out this change in attitude during take off to increase the angle of attack so that a substantially fully automatic take off of the airplane is obtainable.

In Fig. 13 of the drawings, the relative location of the front wheels 11 and the rear wheel 10 of the landing gear with respect to the center of gravity, is disclosed, and, by the shaded area surrounding the center of gravity indicated at c. g., there is purely schematically indicated the permissible range of fore and aft change in location of the center of gravity. With the airplane at rest on the ground, referring now to Fig. 13A, the center of gravity is in the area indicated, and, for the particular airplane disclosed, the lifting surface formed by the wings RW and LW is at an approximately nine degree (9°) angle of attack. The line of thrust P' of the pusher propeller P is so located relative to the landing gear and the center of gravity, that this line of thrust is above the center of gravity so that as the thrust force is applied for take off,

referring now to Fig. 13B, a moment is established acting around the center of gravity tending to nose the airplane down and thus prevent movement of the body B about the center of gravity to increase the angle of attack of the lifting surface.

However, as forward speed of the airplane is increased during take off, the resultant lift indicated by Y developed by the wings RW and LW is increased and as these wings are of the inherently longitudinally stable type, such lift acts upwardly and forward of the center of gravity as shown by Fig. 13B, and produces a stalling moment at small angles of attack which opposes the thrust moment so that the load on the forward elements of the landing gear is reduced and the angle of attack of the wings increased up to that angle at which the lift force on the wing coincides with the center of gravity as shown by Fig. 13C. As this coincidence of the lift force with the center of gravity may take place at an angle of attack less than that desired for take off, I have, in accordance with the principles of this feature of my invention, provided for the application of an additional force acting forward of the center of gravity on the body B to establish a moment acting to raise the forward portion of the body and thereby increase the angle of attack of the wing still further.

Referring now particularly to Figs. 12, 18 and 18a, I have, in the example hereof, provided a coil expansion spring 90 for developing the force of the required magnitude acting to raise the forward portion of the body B about the center of gravity. It so happens that I have mounted the spring 90 around hydraulic cylinder 79 of the common shock absorber unit for the front wheels of the landing gear and between the fixed structure carrying this cylinder and the vertically movable cross-head 82 carried by the piston rod 81a of the shock absorber plunger 81. This force exerting spring 90 is mounted and confined in such operative position as to be constantly under compression and to thereby continuously exert a force acting on the body B in the desired direction. By this construction and mounting a very compact unit is provided occupying a minimum of space for the common shock absorber unit and this force exerting spring.

With the spring 90 so mounted, during take off, when the lift force indicated at Y in Fig. 13C developed by the wings coincides with the center of gravity, the spring 90 exerts an additional force indicated as X in Figs. 13A—B—C—D, of a sufficient magnitude to raise the forward portion of the body B in which the spring is mounted, still further upwardly and thus further increase the angle of attack of the wings until the required angle of attack for take off is reached, as shown by Fig. 13D. Thus, the action of this spring and of the other forces is primarily automatic and the airplane can, in effect, be taken off automatically by simply setting it on its take off run, leaving the additional aerodynamic control available to the pilot in order that he may exercise customary take off and flight maneuvers.

It is here pointed out that the mechanism for increasing the angle of attack of the wings may instead of applying a positive force forward of the center of gravity of the airplane, be mounted and arranged so that the weight on the rear supporting member or members of the landing gear may be utilized by the employment of suitable release mechanism to permit the rear por-

tion of the airplane to gradually sink or lower during take off, thereby increasing the angle of attack. Hence, basically, my invention is not limited to the application of an additional forward, positive force as shown in the specific example, but includes and covers the utilization of the forces developed during take off, outside of the normal forces that may be applied by the pilot's manipulation of the controls, in such a manner as to obtain the desired lift for take off.

The principles and features of the landing gear of my invention, while here shown and specifically described as applied to a gear of the land type, are adapted to landing gear of the water types using pontoons, floats, hulls or other forms of water engaging elements, as well as to landing gear of the land types employing other ground engaging elements than wheels, such for example, as skis, treads and such like.

While the foregoing feature of the invention is of particular utility and efficiency in a truly tailless type of airplane such as that of my present disclosure, yet it is to be understood, as will be obvious, that it is adapted to use with tailless airplanes or tailed airplanes and my invention contemplates and includes such general use of this feature and of the principles of automatic take off here disclosed. Further, while I have shown a spring as the means for generating this additional force for raising the body of the airplane to increase the angle of attack of the wings, my invention is not limited to the specific form of force generating means employed, or, to raising the body of the airplane, for if desired, this force may be applied to a variable incidence wing, or, in fact, to any form of wing of the variable lift types for the purpose of varying the lift of the wings as desired or required for take off.

No claim is made herein to the inventions embodied in the above described and disclosed design and arrangement for "take off," such inventions being disclosed and claimed in my pending U. S. patent application, Ser. No. 613,497, filed August 30, 1945.

Propeller thrust location

The location of the propeller thrust P' (see Fig. 13) above the center of gravity in the tailless types of airplanes, is of material value as an aid to longitudinal control and forms a feature of the tailless type of airplane of the invention here disclosed. For example, when it is desired to fly the airplane slowly in a glide or just prior to landing, the motor is throttled, and due to the reduction or elimination of the thrust P' above the center of gravity, the stalling moment that must be otherwise provided by the longitudinal control is reduced and the pilot has more control available for the high angle of attack maneuvers. When the throttle is opened, the reverse conditions are established, and the pilot has available more control for high speed or low angle of attack maneuvers.

Engine cooling

The engine E, referring now to Fig. 14 of the drawings, is mounted in the upper rear portion of the body B and drives the pusher propeller P through suitable drive shafts 91. This engine E is air cooled and further happens to be of the inverted type. Following a further feature of my invention, I have provided an arrangement for cooling the engine E by circulating air.

Such engine cooling system in the example

hereof provides an air intake 92 at the forward or nose end of the body B which intake opens into an air duct or passage 93 formed in or on the body B and extending downwardly along and following the underside thereof to a point intermediate the length of the body and just forward of the forward end of the engine E, as will be clear from Fig. 14.

The air duct or passage 93 extends rearwardly and upwardly through the body from the lower intermediate portion thereof and is divided by a suitable partition or wall to form the passages or ducts 93a and 93b. Duct 93a extends rearwardly over and around the barrels of the cylinders of the engine E while the duct or passage 93b extends over and across and receives the heads of the engine cylinders at the lower side of such inverted type of engine. Thus arranged, the cylinder barrels extend through and are enclosed by the duct 93a while the cylinder heads are disposed within the duct 93b so that air circulated rearwardly through these ducts circulates over and around the cylinder barrels and the cylinder heads. The ducts or passages 93a and 93b communicate with and discharge into a common outlet 93c at the rear of the engine in the body above the housing or fairing H for the rear wheel 10, so that air, after circulating and cooling the engine, flows downwardly and outwardly through the lower open end of housing H which forms the discharge to atmosphere for the air circulating system.

With the airplane in flight, positive pressure is established at the inlet or intake 92 of the engine cooling air circulating system, while, a suction is established at the discharge or outlet for the air through the lower open end of the rear wheel housing or fairing H, so that, due to this pressure differential, a positive rearward circulation of air for cooling the engine is provided.

The cooling system of the invention provides for circulating air with the airplane taxiing or at rest on the ground. In the example hereof, a fan or blower 100 is mounted in the outlet or discharge 93c from the ducts or passages 93a and 93b. This fan or blower is of the suction type to draw air rearwardly through the passages and discharge it rearwardly from the discharge 93c for circulation downwardly and outwardly through fairing H, and is driven by a suitable drive 101 from the engine drive shafting 91. A suitable clutch mechanism 102 is provided for disengaging the drive 101 from the propeller shafting 91 and this clutch mechanism is automatically operated from the shock absorbing unit for the rear wheel 10 in such a manner that with the airplane on the ground and rear wheel 10 in its raised ground engaging position, the clutch is engaged and the blower or fan is driven to circulate the cooling air through the system, while with the airplane in the air, and the rear wheel 10 moved downwardly, the clutch mechanism is disengaged with the fan or blower inactive. For instance, I may provide, as in the example hereof, an operating cable 103 connected to that portion of the rear wheel shock absorbing unit movable by and with the rear wheel and extending upwardly over any suitable pulleys to the clutch mechanism so that with the airplane on the ground and wheel 10 raised, cable 103 is inactive and the clutch is engaged to drive the blower, while with the airplane in the air and the wheel 10 in its lowered position, the cable 103 is pulled or drawn downwardly to actuate

the clutch mechanism to engage the fan or blower 100 from the propeller drive shaft 91.

A further feature of the cooling system resides in the arrangement for cooling the exhaust lines or pipes 104, referring now to Figs. 14 and 16. The exhaust pipes 104 extend downwardly through the body B, as indicated by Fig. 14, and each of these pipes extends downwardly through a cylindrical tube or jacket 105 which is spaced therefrom to provide the air circulating passage 105a around an exhaust pipe 104. The upper end of this casing or tube 105 is open and has an enlarged diameter air intake end 105b, while the lower end of the tube or casing has a restricted or reduced diameter outlet 105c, thus, in effect forming a venturi so that circulation of air downwardly through the tube over and around an exhaust pipe is induced by the exhaust gases discharged from the lower end of the exhaust pipe or stick 104 in, to and outwardly through the lower restricted discharge end 105c of the tube 105.

The inventions embodied in the foregoing engine cooling system and arrangement, are not claimed herein, but are disclosed, described and claimed in my pending U. S. patent application, Ser. No. 613,499, filed August 30, 1945.

It is also evident that various changes, modifications, variations, substitutions, eliminations and additions might be resorted to without departing from the spirit and scope of my invention and hence, I do not wish to limit myself in all respects to the exact and specific disclosures hereof.

What I claim is:

1. An airplane of the truly tailless type embodying an inherently longitudinally stable wing having a substantial positive value C_{mo} at zero (0) lift, a longitudinal control for the airplane including a longitudinal control surface mounted for displacement between neutral and control positions relative to said wing, control mechanism for displacing said longitudinal control surface, a lateral control for the airplane including a roll control surface independent of said longitudinal control surface and being mounted for displacement between neutral and control positions for establishing rolling moments on the airplane, the center of gravity of the airplane being located forward of the average fifty percent (50%) chord station of the maximum chord of the wing, said wing being without substantial sweepback whereby said longitudinal control surface when displaced to control positions establishes substantial pitching moments on the airplane, a movable surface mounted for displacement to positions developing a lift acting to substantially neutralize the adverse lift developed by said longitudinal control surface in control positions thereof, respectively, and mechanism for displacing said lift neutralizing surface.

2. An airplane of the truly tailless type embodying an inherently longitudinally stable wing having a substantial positive value C_{mo} at zero (0) lift, a longitudinal control system for the airplane including a longitudinal control surface forming a trailing portion of said wing, said control surface being vertically displaceable between neutral position and control positions, mechanism for vertically displacing said longitudinal control surface between neutral position and control positions for longitudinally controlling the airplane, a lateral control system for the airplane including a roll control surface for dis-

placement between neutral position and control positions establishing rolling moments for laterally controlling the airplane, control mechanism for displacing said roll control surface between neutral and control positions, a movable surface for displacement to positions to develop a lift force of a magnitude to substantially neutralize the lift forces developed by said longitudinal control surface in control positions thereof, respectively, mechanism for displacing said lift neutralizing surface, the center of gravity of the airplane being located forward of the average fifty percent (50%) chord station of the maximum chord of the wing and said inherently longitudinally stable wing being without substantial sweepback whereby said longitudinal control surface when vertically displaced to control positions establishes substantial pitching moments on the airplane for longitudinal control.

3. An airplane of the truly tailless type embodying an inherently longitudinally stable wing having a substantial positive value C_{mo} at zero (0) lift, there being no aerodynamic structure for the airplane substantially to the rear of the trailing edge of said wing, a longitudinal control for the airplane including a longitudinal control surface mounted for displacement between neutral position and control positions, control mechanism displacing said longitudinal control surface, an adverse lift neutralizing surface mounted for movement to positions substantially neutralizing the adverse lift developed by said longitudinal control surface in control positions thereof, respectively, the center of gravity of the airplane being located forward of the average fifty percent (50%) chord station of the maximum chord of the wing, and said wing being without substantial sweepback whereby said longitudinal control surface when displaced to control positions establishes substantial pitching moments on the airplane.

4. An airplane of the truly tailless type embodying an inherently longitudinally stable wing having a substantial positive value C_{mo} at zero (0) lift, a longitudinal control system for the airplane including a longitudinal control surface forming a trailing portion of said wing symmetrical with the central portion of the wing, said control surface being displaceable between neutral position and control positions, mechanism for displacing said longitudinal control surface, movable surface forming a trailing portion of said wing outboard of said longitudinal control surface, said outboard surface being mounted for displacement to positions establishing lift substantially neutralizing adverse lift developed by said longitudinal control surface in control positions thereof, respectively, the center of gravity of the airplane being located forward of the average fifty percent (50%) chord station of the maximum chord of the wing, and said wing being without substantial sweepback whereby said longitudinal control surface when displaced by said mechanism establishes substantial pitching moments on the airplane.

5. An airplane of the truly tailless type embodying an inherently longitudinally stable wing having a substantial positive value C_{mo} at zero (0) lift, a longitudinal control system for the airplane including a longitudinal control surface forming a trailing portion of said wing symmetrical with the central portion of the wing, said control surface being vertically displaceable between neutral position and control positions, mechanism for vertically displacing said longitudinal

control surface, roll control surfaces forming the trailing portions of said wing at opposite sides and outboard of said longitudinal control surface, respectively, for displacement to establish rolling moments for laterally controlling the airplane, control mechanism for displacing said roll control surfaces for lateral control, means for simultaneously displacing said roll control surfaces in the same direction independently of said longitudinal control surface to positions developing a lift for substantially neutralizing adverse lift developed by said longitudinal control surface in control positions thereof, respectively, the center of gravity of the airplane being located forward of the average fifty percent (50%) chord station of the maximum chord of the wing, and said wing being without substantial sweepback whereby said longitudinal control surface when vertically displaced by said mechanism establishes substantial pitching moments on the airplane for longitudinal control.

6. An airplane of the truly tailless type embodying an inherently longitudinally stable wing having a substantial positive value C_{mo} at zero (0) lift, a longitudinal control surface forming a portion of said wing and being mounted for vertical displacement between neutral position and control positions to establish pitching moments for longitudinally controlling the airplane, control mechanism for vertically displacing said longitudinal control surface, the center of gravity of the airplane being located forward of the average fifty percent (50%) chord station of the maximum chord of the wing, there being no aerodynamic structure for the airplane substantially to the rear of the trailing edge of said wing, said wing being without substantial sweepback whereby said longitudinal control surface when vertically displaced to control positions establishes substantial pitching moments on the airplane for longitudinal control, a movable surface mounted for displacement to positions establishing a lift for longitudinally balancing the airplane to compensate for movement of the center of gravity of the airplane caused by variations in the load of the airplane, and means independent of said longitudinal control surface for selectively adjusting said lift surface to positions longitudinally balancing the airplane.

7. A tailless airplane having an inherently longitudinally stable wing forming the lift surface for the airplane, a longitudinal control surface forming a portion of said wing and being mounted for movement between neutral positions and control positions establishing pitching moments for longitudinally controlling the airplane, control mechanism for moving said longitudinal control surface between neutral positions and control positions, a movable surface forming a portion of said wing for selective actuation independently of said longitudinal control surface to adjusted positions to compensate for changes in center of gravity location for the airplane caused by variations in the airplane load to thereby longitudinally balance the airplane, and means operable independently of said control mechanism for actuating said movable surface to and from adjusted positions independently of said longitudinal control surface, to return the longitudinal control surface to neutral positions.

8. A tailless airplane including a wing providing the lifting surface for the airplane, a longitudinal control surface forming a portion of said wing within the normal plan of the wing and being mounted for displacement between neutral

position and control positions for establishing pitching moments for longitudinally controlling the airplane, control mechanism for displacing said control surface, a surface forming a portion of said wing and being mounted for displacement to positions developing a lift substantially neutralizing the adverse lift developed by said longitudinal control surface in any control position of the latter surface, and means for selectively and independently displacing said lift neutralizing surface to adjusted positions relative to the control positions, respectively, of said longitudinal control surface.

9. A tailless airplane having an inherently longitudinally stable wing arrangement forming a lift surface for the airplane, a longitudinal control for the airplane embodying a longitudinal control surface forming a portion of said wing arrangement for movement between neutral position and control positions establishing pitching moments acting in the desired direction for longitudinally controlling the airplane, an adverse lift force neutralizing surface operable independently of said longitudinal control surface for selective adjustment to positions relative to the control positions, respectively, of said control surface to reduce the adverse lift developed by said control surface in any control position thereof, and means for selectively and independently operating said adverse lift neutralizing surface to adjusted positions relative to the control positions, respectively, of said longitudinal control surface.

10. A tailless airplane having an inherently longitudinally stable wing forming a lift surface for the airplane, a longitudinal control for the airplane embodying a movable control surface forming a portion of said wing for movement between neutral positions and control positions establishing pitching moments for longitudinally controlling the airplane, control mechanism for moving said longitudinal control surface between neutral positions and control positions, an adverse lift force neutralizing surface forming a portion of said wing and being mounted for actuation independently of said movable longitudinal control surface for selective adjustment to positions relative to the control positions, respectively, of said control surface to substantially neutralize adverse lift developed by said longitudinal control surface, means independent of said control mechanism for selectively and independently actuating said neutralizing surface to adjusted positions relative to the control positions, respectively, of said longitudinal control surface, and said operating means for the neutralizing surface being also operable independently of said control mechanism to adjust said neutralizing surface independently of said longitudinal control surface to return said longitudinal control surface to neutral positions to longitudinally balance the airplane by compensating for changes in center of gravity location caused by load variations in the airplane.

11. In a tailless airplane an inherently longitudinally stable wing arrangement forming a lift surface for the airplane, a longitudinal control for the airplane including a longitudinal control surface forming a portion of the wing arrangement, operating means for moving said control surface between neutral position and control positions establishing pitching moments acting in the desired direction for longitudinally controlling the airplane, an adverse lift neutralizing surface forming a portion of said wing arrange-

ment and being mounted for movement to positions for neutralizing adverse lift developed by said longitudinal control surface, and means for independently and selectively moving said neutralizing surface to positions relative to the control positions of said longitudinal control surface, respectively, to substantially neutralize the adverse lift developed by the latter surface in any control position thereof.

12. A tailless airplane embodying an inherently longitudinally stable wing forming the lift surface for the airplane, a longitudinal control for the airplane including a longitudinal control surface forming a portion of the wing within the plan thereof and being vertically displaceable between neutral and control positions establishing pitching moments acting in the desired direction for longitudinally controlling the airplane, an adverse lift neutralizing surface forming a portion of the wing within the plan thereof and being vertically displaceable to positions for neutralizing adverse lift developed by said longitudinal control surface in control positions thereof, and mechanisms for vertically displacing said neutralizing surface independently of said longitudinal control surface to selected positions of displacement relative to the displacement of said control surface to substantially neutralize adverse lift developed by the control surface in any control position thereof throughout the range of vertical displacement of said longitudinal control surface.

13. A tailless airplane embodying an inherently longitudinally stable wing forming the lift surface for the airplane, a longitudinal control surface forming a portion of said wing and being vertically displaceable between neutral position and control positions establishing pitching moments acting in the desired direction for longitudinally controlling the airplane, mechanism for vertically displacing said longitudinal control surface, an adverse lift neutralizing surface forming a portion of said wing and being vertically displaceable to positions relative to the control positions, respectively, of said control surface for neutralizing adverse lift developed by the latter surface, and means for displacing said neutralizing surface independently of said control surface to such a position relative to any control position of the control surface that the adverse lift developed by said control surface is substantially balanced out by said neutralizing surface.

14. A tailless airplane having an inherently longitudinally stable wing forming a lift surface for the airplane, a lateral control for the airplane embodying opposite ailerons for displacement to positions establishing rolling moments acting in the desired direction to laterally control the airplane, a longitudinal control for the airplane embodying a movable control surface forming a part of said wing for movement between neutral position and control positions establishing pitching moments acting in the desired direction for longitudinally controlling the airplane, control mechanism operatively associated with said opposite ailerons and with said longitudinal control surface for operating the said ailerons and longitudinal control surface, an adverse lift force neutralizing surface operable independently of said longitudinal control surface for selective adjustment to positions relative to the control positions, respectively, of said control surface to substantially neutralize adverse lift developed by said control surface in any control position thereof, and means independent of said control mechanism for selectively operating said adverse lift

neutralizing surface to adjusted positions relative to the control positions, respectively, of said longitudinal control surface.

15. A tailless airplane having an inherently longitudinally stable wing arrangement providing opposite wings for the airplane, a lateral control for the airplane embodying ailerons on the outboard portions of said opposite wings, respectively, said ailerons being displaceable to positions establishing rolling moments acting in the desired direction to laterally control the airplane, a longitudinal control for the airplane embodying a vertically displaceable control surface forming a portion of said wing arrangement and located inboard of said opposite ailerons for movement between neutral position and control positions establishing pitching moments acting in the desired direction for longitudinally controlling the airplane, control mechanism operatively coupled with said opposite ailerons and with said longitudinal control surface independently for operating the said ailerons and longitudinal control surface for laterally and longitudinally controlling the airplane, an adverse lift force neutralizing surface operable independently of said longitudinal control surface and said ailerons for selective adjustment to positions relative to the control positions, respectively, of said longitudinal control surface to substantially neutralize the adverse lift developed by said control surface in any position thereof, and means independent of said control mechanism for selectively operating said adverse lift neutralizing surface to adjusted position relative to any control position of said longitudinal control surface.

16. A tailless airplane, including an inherently longitudinally stable wing forming the lift surface for the airplane, a longitudinal control embodying a vertically displaceable control surface forming a portion of said wing for displacement between neutral position and control positions to establish pitching moments acting in the desired direction for longitudinally controlling the airplane, control mechanism for displacing said control surface for longitudinal control of the airplane, and means operable independently of said control mechanism for selective adjustment in accordance with the conditions of adverse lift developed by said longitudinal control surface in control positions thereof for neutralizing the adverse lift so developed at any control position of said control surface throughout its operating range.

17. A tailless airplane including an inherently longitudinally stable wing forming the lift surface for the airplane, a longitudinal control embodying a vertically displaceable control surface forming a trailing portion of said wing for displacement between neutral position and control positions to establish pitching moments acting in the desired direction for longitudinally controlling the airplane, control mechanism for displacing said control surface for longitudinal control of the airplane, aerodynamic means operable independently of said longitudinal control surface for developing a lift acting in a direction opposite to the lift developed by said longitudinal control surface in control positions thereof to thereby neutralize the lift developed by said control surface at any control position thereof throughout its operating range, and means independent of said control mechanism for selectively operating said aerodynamic means to develop a lift of a magnitude to neutralize the lift devel-

oped at any control position of said longitudinal control surface, respectively.

18. In a tailless airplane, in combination, an inherently longitudinally stable wing forming the lift surface for the airplane, a longitudinal control surface mounted for movement between neutral position and control positions at which said surface develops pitching moments acting in the desired direction for longitudinally controlling the airplane, control mechanism for moving said longitudinal control surface between neutral and control positions, means operable independently of said longitudinal control surface and of said operating mechanism for selective adjustment to substantially neutralize adverse lift of the magnitude developed by said longitudinal control surface at any control position thereof throughout its operating range.

19. In a tailless airplane, in combination, an inherently longitudinally stable wing forming the lift surface for the airplane, a longitudinal control surface mounted for movement between neutral position and control positions in which such surface develops pitching moments acting in the desired direction for longitudinally controlling the airplane, means operable independently of said longitudinal control surface for selective adjustment to substantially neutralize that adverse lift developed by said longitudinal control surface in any control position of the latter throughout its operating range, and irreversible mechanism directly coupled with said adverse lift neutralizing means for selective operation of the latter.

20. In a tailless airplane, in combination, an inherently longitudinally stable wing forming the lift surface for the airplane, a longitudinal control surface mounted for movement between neutral position and control positions in which such surface develops pitching moments acting in the desired direction for longitudinally controlling the airplane, control mechanism for moving said longitudinal control surface between neutral and control positions, means operable independently of said longitudinal control surface for selective adjustment to substantially neutralize adverse lift of the magnitude developed by said longitudinal control surface in any control position of the latter throughout its operating range, and irreversible mechanism operatively associated with said adverse lift neutralizing means for operation independently of said control mechanism for selective operation of said adverse lift neutralizing means in accordance with the control position of said longitudinal control surface.

21. In a tailless airplane, in combination, an inherently longitudinally stable wing forming the lift surface for the airplane, a longitudinal control surface forming a trailing portion of said wing and being mounted for vertical displacement between neutral position and control positions at which said surface develops pitching moments acting in the desired direction for longitudinally controlling the airplane, control mechanism for vertically displacing said longitudinal control surface between neutral and control positions for longitudinally controlling the airplane, an adverse lift neutralizing surface forming a portion of said wing and being mounted for vertical displacement to a position for developing a lift force of the desired magnitude acting in the desired direction, and irreversible mechanism operatively coupled with said adverse lift neutralizing surface for actuation independently of said control mechanism for selective displacement of said adverse lift neutralizing surface to an adjusted posi-

tion at which the adverse lift developed by the longitudinal control surface in any control position thereof is substantially neutralized by the lift developed by said neutralizing surface.

22. In a tailless airplane, in combination, an inherently longitudinally stable wing forming the lift surface for the airplane, a longitudinal control surface mounted for displacement between neutral position and control positions at which said surface develops pitching moments acting in the desired direction for longitudinally controlling the airplane, a surface movably mounted for displacement to positions substantially reducing the adverse lift developed by said longitudinal control surface in control positions thereof, respectively, pilot operated control means for displacing said longitudinal control surface to control positions, and mechanism of the irreversible type directly operatively associating said pilot operated control means with said adverse lift neutralizing surface for simultaneous displacement of the latter surface by actuation of said pilot operated control means, to positions substantially reducing adverse lift developed by said longitudinal control surface in its control positions, respectively, throughout the operating range of the longitudinal control surface.

23. In a tailless airplane, in combination, an inherently longitudinally stable wing, a longitudinal control surface mounted for vertical angular displacement relative to said wing for developing pitching moments acting in the desired direction to longitudinally control the airplane, an adverse lift neutralizing surface mounted for vertical angular displacement relative to said wing to adjusted positions relative to the control positions of said longitudinal control surface, respectively, for neutralizing adverse lift developed by said control surface, pilot operated control mechanism for angularly vertically displacing said longitudinal control surface to control positions, and mechanism of the irreversible type operatively coupling said adverse lift neutralizing surface with said pilot operated mechanism for simultaneous displacement of said neutralizing surface in a direction opposite the direction of displacement of said longitudinal control surface to thereby substantially reduce the adverse lift developed by said longitudinal control surface in any control position thereof throughout the operating range of said longitudinal control surface.

24. In a tailless airplane, in combination, an inherently longitudinally stable wing forming the lift surface for the airplane, a longitudinal control surface forming a portion of the wing and being mounted for vertical angular displacement from neutral position to control positions at which pitching moments are developed acting in the desired direction for longitudinally controlling the airplane, an adverse lift neutralizing surface forming a portion of said wing and being mounted for vertical angular displacement relative to the wing and to said longitudinal control surface for establishing a lift substantially neutralizing the adverse lift developed by the longitudinal control surface in control positions thereof, the said longitudinal control surface being mounted on and carried by said neutralizing surface, control means for vertically angularly displacing said longitudinal control surface, and mechanism for displacing said neutralizing surface independently of the displacement of said longitudinal control surface to substantially neutralize the adverse lift developed by the latter surface in

any control position thereof throughout its operating range.

25. In a tailless airplane, in combination, an inherently longitudinally stable wing, a longitudinal control surface forming a trailing portion of said wing and being mounted for vertical displacement relative to said wing to control positions at which said surface develops pitching moments acting in the desired direction for longitudinally controlling the airplane, an adverse lift neutralizing surface forming a portion of said wing and being mounted for vertical displacement relative to the wing and to said longitudinal control surface for establishing a lift of a magnitude to substantially neutralize the adverse lift developed by said longitudinal control surface in any control position thereof, respectively, the said longitudinal control surface being mounted along the trailing edge of said adverse lift neutralizing surface in rearward continuation of said surface, control mechanism for vertically displacing said longitudinal control surface on and relative to said neutralizing surface independently of the vertical displacement of the neutralizing surface, and means for displacing said neutralizing surface relative to and independently of said longitudinal control surface in any position of the latter to selectively position said neutralizing surface relative to any control position of said longitudinal control surface.

26. A tailless airplane including a wing arrangement providing opposite wings for the airplane, a lateral control for the airplane including ailerons mounted on said opposite wings, respectively, for displacement to develop rolling moments for laterally controlling the airplane, a longitudinal control for the airplane embodying a control surface forming a portion of the wing arrangement and being mounted for vertical angular displacement from neutral position to control positions at which pitching moments are developed acting in the desired direction for longitudinally controlling the airplane, an adverse lift neutralizing surface forming a portion of said wing arrangement and being mounted for selective vertical displacement to positions establishing a lift substantially neutralizing the adverse lift developed by said longitudinal control surface in control positions thereof, respectively, the said longitudinal control surface being mounted on and carried by said neutralizing surface, control means for displacing said longitudinal control surface independently of said adverse lift neutralizing surface, and mechanism for displacing said neutralizing surface independently of the displacement of said longitudinal control surface to selectively adjusted positions relative to the control positions, respectively, of said longitudinal control surface.

27. In a tailless airplane, an inherently longitudinally stable wing providing the lift surface for the airplane, a lateral control system including opposite ailerons mounted on said wing at the tip portions thereof, respectively, a longitudinal control system for the airplane including a control surface forming a trailing portion of said wing intermediate said opposite ailerons and being mounted for vertical displacement to establish pitching moments acting in the desired direction for longitudinally controlling the airplane, an adverse lift neutralizing surface forming a portion of said wing intermediate said opposite ailerons and being mounted for vertical displacement to develop a lift for neutralizing the

adverse lift established by said longitudinal control surface in control positions thereof, said longitudinal control surface being mounted on and carried by said neutralizing surface as a trailing portion thereof, control means for vertically displacing said longitudinal control surface independently of said neutralizing surface, and mechanism for vertically displacing said neutralizing surface independently of and relative to said longitudinal control surface.

28. In a tailless airplane, a wing providing the lift surface for the airplane, a lateral control system including opposite lateral control surfaces mounted on the opposite outboard portions of said wing, respectively, a longitudinal control system for the airplane including a control surface forming a trailing portion of said wing intermediate said opposite lateral control surfaces, said longitudinal control surface being mounted for vertical displacement to control positions for developing pitching moments acting in the desired direction for longitudinally controlling the airplane, an adverse lift neutralizing surface forming a portion of said wing forward of said longitudinal control surface and intermediate said opposite lateral control surfaces, said longitudinal control surface being mounted on and carried by the trailing portion of said neutralizing surface for vertical displacement thereon independently thereof to positions at which a lift is developed of a magnitude for neutralization the adverse lift established, respectively, by said longitudinal control surface in control positions thereof, control means for vertically displacing said longitudinal control surface independently of said neutralizing surface in any position of the latter surface, and independent mechanism for vertically selectively displacing said neutralizing surface to positions relative to the control positions of said longitudinal control surface, respectively, at which the adverse lift developed by said longitudinal control surface is substantially neutralized by the lift developed by said neutralizing surface.

29. In a tailless airplane, a wing providing the lift surface for the airplane, a lateral control system including opposite lateral control surfaces mounted on the outboard portions of said wing, respectively, for displacement to develop rolling moments for laterally controlling the airplane, control mechanism operatively associated with said lateral control surfaces for displacing the same for lateral control, a longitudinal control system for the airplane, including a control surface forming a trailing portion of said wing inboard of said lateral control surfaces, said longitudinal control surface being mounted for vertical displacement to control positions on said wing for developing pitching moments acting in the desired direction for longitudinally controlling the airplane, an adverse lift neutralizing surface forming a portion of said wing forward of said longitudinal control surface, said longitudinal control surface being mounted on and carried by the trailing portion of said neutralizing surface for vertical displacement thereon independently thereof to positions at which a lift is developed of a magnitude for substantially neutralizing the adverse lift established, respectively, by said longitudinal control surface in control positions thereof, said control means being operatively coupled with said longitudinal control surface for operation to displace said surface on said neutralizing surface for longitudinal control, and mechanism of the irreversible type op-

eratively directly coupled with said neutralizing surface independently of said pilot operated control means, for selectively displacing said neutralizing surface to adverse lift neutralizing positions, respectively, relative to the control positions of said longitudinal control surface.

30. In a tailless airplane, a wing providing the lift surface for the airplane, a lateral control system including opposite lateral control surfaces mounted on the outboard portions of said wing, respectively, for displacement to develop rolling moments for laterally controlling the airplane, control mechanism operatively associated with said lateral control surfaces for displacing the same for lateral control, a longitudinal control system for the airplane, including a control surface forming a trailing portion of said wing inboard of said lateral control surfaces, said longitudinal control surface being mounted for vertical displacement to control positions on said wing for developing pitching moments acting in the desired direction for longitudinally controlling the airplane, an adverse lift neutralizing surface forming a portion of said wing forward of said longitudinal control surface, said longitudinal control surface being mounted on and carried by the trailing portion of said neutralizing surface for vertical displacement thereon independently thereof to positions at which a lift is developed of a magnitude for substantially neutralizing the adverse lift established, respectively, by said longitudinal control surface in control positions thereof, said control means being operatively coupled with said longitudinal control surface for operation to displace said surface on said neutralizing surface for longitudinal control, and mechanism of the irreversible type operatively coupling said neutralizing surface with said pilot operated control means whereby operation of the latter means to displace said longitudinal control surface for longitudinal control causes simultaneous vertical displacement of said neutralizing surface in the opposite direction.

31. In a tailless airplane, an inherently longitudinally stable wing forming the lift surface for the airplane, a longitudinal control surface forming a portion of said wing and being displaceable to control positions relative to the wing for developing pitching moments acting in the desired direction to longitudinally control the airplane, opposite lateral control surfaces displaceable for developing rolling moments acting in the desired direction for laterally controlling the airplane, a control system operatively connected with said longitudinal control surface and with said opposite lateral control surfaces for displacing the longitudinal control and the lateral control surfaces for longitudinally and laterally controlling the airplane, irreversible mechanism operatively associated with said opposite lateral control surfaces for simultaneously vertically displacing said lateral control surfaces in the same direction to positions at which a lift is developed substantially balancing out the adverse lift developed by said longitudinal control surface in control positions thereof, respectively, said irreversible mechanism being operable independently of the operation of said opposite lateral control surfaces for roll control by the said pilot operated control means, and said opposite roll control surfaces being displaceable by said pilot operated control means for roll control in any position thereof to which displaced by said independent irreversible mechanism.

32. In a tailless airplane, an inherently longitudinally stable wing forming the lift surface for the airplane, opposite lateral control surfaces mounted on the opposite outboard portions, respectively, of said wing for displacement to control positions for developing rolling moments acting in the desired direction for laterally controlling the airplane, a longitudinal control surface forming a portion of said wing inboard of said lateral control surface and being vertically displaceable thereon to control positions relative to the wing for developing pitching moments acting in the desired direction to longitudinally control the airplane, a control system operatively connected with said longitudinal control surface and with said opposite lateral control surface for selectively displacing the longitudinal control surface and the lateral control surfaces for longitudinally and laterally controlling the airplane, and independent means for simultaneously displacing said opposite lateral control surfaces in the same direction to positions at which a lift is established substantially neutralizing the adverse lift developed by said longitudinal control surface in any control position thereof.

33. In a tailless airplane an inherently longitudinally stable wing, a lateral control system for the airplane including opposite lateral control surfaces for displacement to develop rolling moments acting in the desired direction to laterally control the airplane, a longitudinal control surface forming a portion of said wing and being mounted for displacement to control positions at which said surface develops pitching moments acting in the desired direction to longitudinally control the airplane, a control mechanism for displacing said opposite lateral control surfaces for laterally controlling the airplane, and means for displacing said lateral control surfaces independently of said pilot operated control mechanism to a position for developing a lift acting to neutralize the adverse lift developed by said longitudinal control surface in any control position of the latter surface, said lateral control surfaces being displaceable by said control mechanism for lateral control in any adverse lift neutralizing position to which displaced by said means.

34. In a tailless airplane, in combination, an inherently longitudinally stable wing, a longitudinal control surface forming a portion of said wing and being mounted for vertical angular displacement relative to the wing to positions at which pitching moments are developed acting in the desired direction to longitudinally control the airplane, an adverse lift neutralizing surface forming a portion of said wing forward of said longitudinal control surface and being mounted for vertical angular displacement to positions at which a lift is developed to substantially neutralize the adverse lift developed by said longitudinal control surface in any control position thereof, said adverse lift neutralizing surface being mounted on and carried by said longitudinal control surface, control means directly operatively coupled with said longitudinal control surface for angularly displacing the same to control positions, and irreversible mechanism operatively connecting said control means with said adverse lift neutralizing surface for operation by said control means to simultaneously and differentially angularly displace said adverse lift neutralizing surface relative to and in accordance with the control position and direction to

which said longitudinal control surface is displaced for longitudinally controlling the airplane by operation of the said control means.

35. In a tailless airplane, a wing forming the lift surface for the airplane, a longitudinal control surface mounted above the wing for movement between neutral position and control positions in which said surface establishes stalling moments, a longitudinal control surface mounted below the wing for movement between neutral position and control positions in which said surface establishes diving moments, and control means for independently actuating said upper and lower control surfaces, respectively, for longitudinally controlling the airplane.

36. In a tailless airplane, a wing forming the lift surface for the airplane, a longitudinal control surface mounted above the wing within the plan thereof for movement between neutral position and control positions in which said surface establishes stalling moments, a longitudinal control surface mounted below the wing within the plan thereof for movement between neutral position and control positions in which said surface establishes diving moments, and control means for actuating said upper and lower longitudinal control surfaces for establishing pitching moments for longitudinally controlling the airplane.

37. In a tailless airplane, an inherently longitudinally stable wing, a vertically disposed laterally displaceable longitudinal control surface mounted above the wing within the plan thereof for establishing stalling moments, a vertically disposed laterally displaceable longitudinal control surface mounted below the wing within the plan thereof for establishing diving moments, and control means for independently actuating said upper and lower control surfaces, respectively, for longitudinally controlling the airplane.

38. In a tailless airplane, an inherently longitudinally stable wing forming the lift surface for the airplane, vertically disposed laterally displaceable longitudinal control surfaces spaced along the span of the wing at the upper side thereof for establishing stalling moments, vertically disposed laterally displaceable longitudinal control surfaces spaced along the span of and below the wing for establishing diving moments, and control mechanism for simultaneously laterally displacing either said upper surfaces or said lower surfaces, for longitudinal control of the airplane.

39. In a tailless airplane, an inherently longitudinally stable wing forming the lift surface for the airplane, a directional control system for the airplane including vertically disposed laterally displaceable rudder surfaces mounted on the wing within the plan thereof at the upper side of the wing adjacent the opposite wing tips, respectively, stop means for maintaining said rudder surfaces against lateral displacement inwardly from normal neutral position, control mechanism for selectively laterally displacing either of said rudder surfaces outwardly to control positions to establish yawing moments acting in the desired direction to directionally control the airplane, and each of said rudder surfaces having the inboard side thereof of greater camber than the outboard side whereby forces are developed by the air flow reaction on each rudder surface to maintain the rudder surface against outward displacement from neutral position to

cause each rudder surface to act as vertical fin area for directional stability.

40. In a tailless airplane, a wing forming the lift surface for the airplane, a directional control system for the airplane including vertically disposed rudder surfaces on the wing within the plan thereof at the upper side of the wing adjacent the opposite wing tips, respectively, each of said rudder surfaces being mounted for lateral displacement between normal neutral position and control positions displaced outwardly, the upper side of said wing being unobstructed forward of the leading edge of each of said rudder surfaces for uninterrupted air flow reaction on said surfaces, stop means for maintaining each rudder surface against lateral displacement inwardly from normal neutral position, control mechanism for selectively laterally displacing either of said rudders outwardly from neutral position to control positions establishing yawing moments for directionally controlling the airplane, and each of said rudders having the inboard side thereof of greater camber than the outboard side whereby the air flow reaction thereon establishes forces acting on each surface tending to maintain the surface against outward displacement.

41. In an airplane, a wing, a control system for the airplane including, a vertically disposed control surface mounted on said wing spaced a distance outwardly from the longitudinal axis of the airplane for lateral displacement from normal neutral position outwardly in a direction away from the longitudinal axis of the airplane to control positions establishing yawing moments acting in the desired direction, means for maintaining said control surface against inward displacement from normal neutral control position, control mechanism for laterally displacing said control surface outwardly from neutral position to control positions, said control surface being outwardly displaceable independently of said control mechanism, and the said control surface having the inboard side of greater camber than the outboard side thereof, whereby forces are established by the reaction of the air flow on said surface acting in a direction to maintain the control surface against outward displacement.

42. In an airplane, a wing, a control system for the airplane including, a vertically disposed control surface mounted on said wing spaced a distance outwardly from the longitudinal axis of the airplane and located within the plan of the wing for lateral displacement from normal neutral position outwardly in a direction away from the

longitudinal axis of the airplane to control positions for establishing yawing moments, said wing being unobstructed forward of the leading edge of said control surface, means for positively maintaining said control surface against inward displacement from normal neutral position, control mechanism for laterally displacing said control surface outwardly to control positions, said control surface being outwardly displaceable independently of said control mechanism, and aerodynamic means associated with said control surface and disposed in the airflow for establishing forces by the reaction of the airflow on said means to maintain said control surface against outward displacement when said control mechanism is inactive.

43. In an airplane, a wing, a control surface on the wing, said control surface being pivotally connected to adjacent structure of the wing for vertical displacement along the horizontally disposed hinge axis, there being a gap along the hinge axis of said control surface between said surface and the adjacent wing structure by which air may pass through the wing, mechanism for vertically displacing said control surface, said mechanism including a pilot actuated control member, and means closing the gap along the hinge axis of said control surface to an extent to control the passage of air through such gap to correlate the movement of the pilot actuated control member to both the magnitude of the force and the angular displacement of the control member to thereby adjust the control reaction from said control member on the pilot.

44. In an airplane, a wing, control surfaces at opposite portions of said wing, said control surfaces being each pivotally connected to the wing for vertical displacement along horizontally disposed hinge axes, each control surface being so mounted relative to the wing structure as to provide a gap along the hinge axes of the control surface by which air may pass through the wing, mechanism for vertically displacing said control surfaces, said mechanism including a pilot actuated control member, and means embodying a strip of material removably secured over the gap along the hinge axes of each control surface to close such gap against passage of air there-through to such an extent so as to correlate the movement of the pilot actuated control member to both the magnitude of the force and the angular displacement of the control member on the pilot.

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