

Jan. 4, 1938.

J. McK. BALLOU

2,104,006

AIRPLANE

Filed June 30, 1933

3 Sheets-Sheet 1

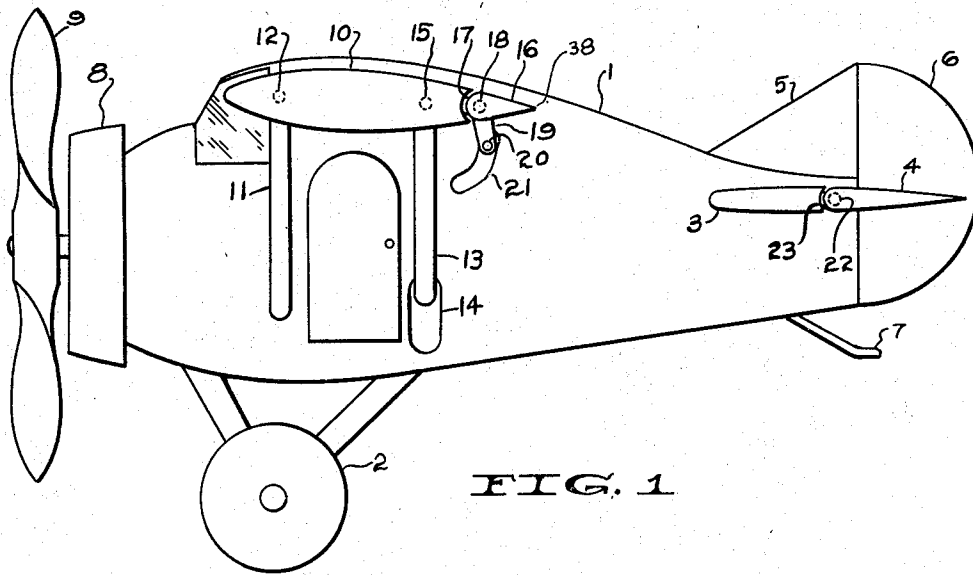


FIG. 1

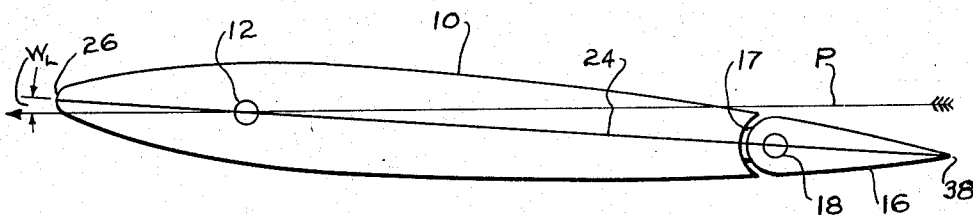


FIG. 2

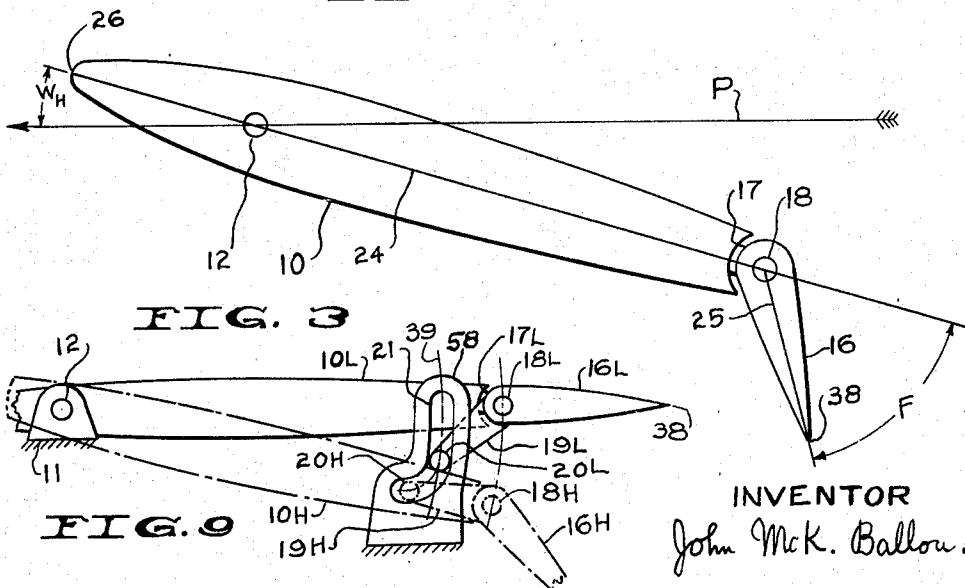


FIG. 3

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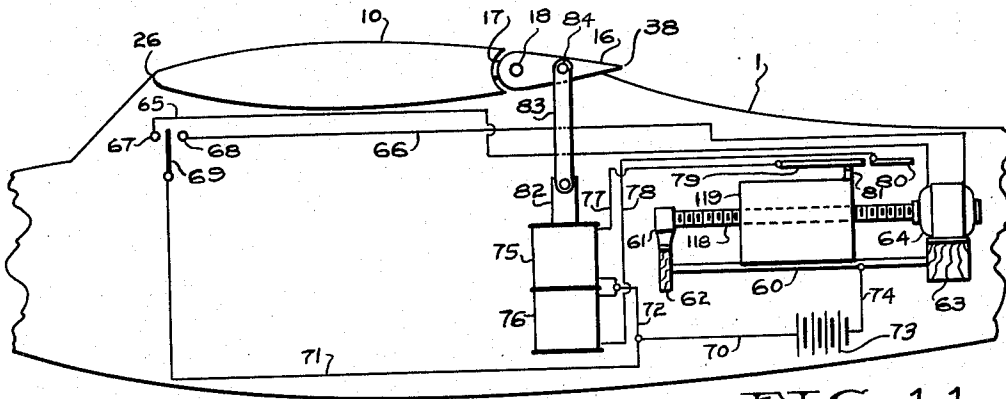


FIG. 11

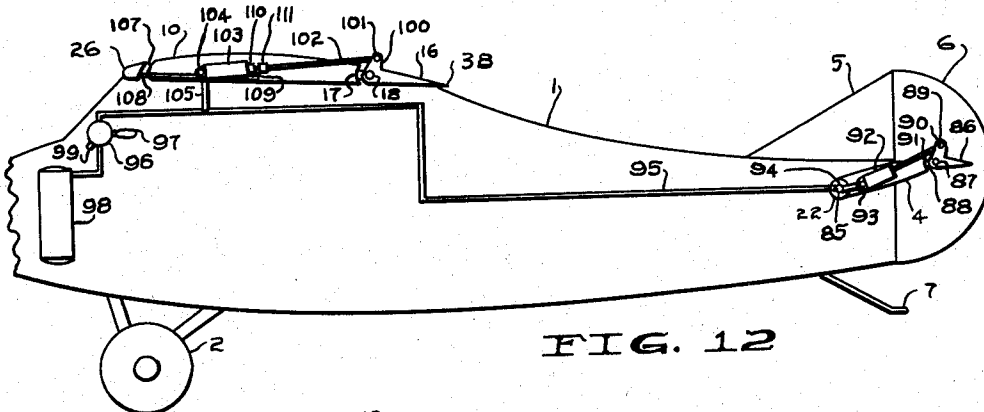


FIG. 12

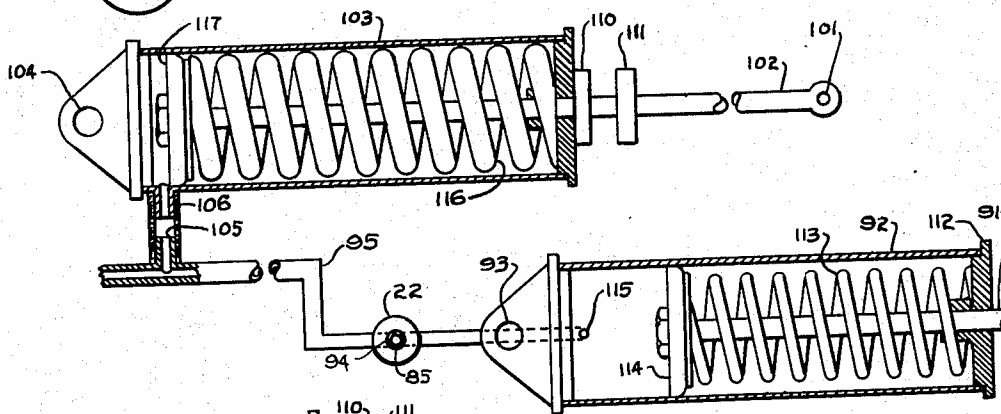


FIG. 13

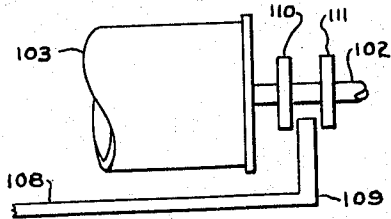


FIG. 14

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AIRPLANE

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7 Claims. (Cl. 244—42)

This invention relates to airplanes in general, and more particularly to the class of airplanes equipped with lift increasing devices.

I am aware that others have constructed airplanes wherein devices have been incorporated for the purpose of increasing the maximum lift coefficient of the airplane, with varying degrees of success. Many devices have been suggested heretofore, which, when actively associated with the wings of airplanes, increase the combined lift coefficient of wing plus the device. For simplicity, hereinafter such devices will be designated lift augmenters. Examples of devices suitable for such purposes, that have become known, may be found in United States patents, Numbers 1,862,902, 1,875,465, 1,875,593, 1,893,064, and 1,893,065. There are numerous other examples to be found in domestic and foreign art, but the examples above recited are representative and will serve to familiarize anyone skilled in the art with the general nature of this class of device. There have been certain cases where airplanes have been constructed according to some of the above as well as other designs of like nature that have been well known for their excellent performance.

However, up to the present, the most satisfactory means for availing oneself of the full benefits to be derived from devices of this class had remained undiscovered, so far as applicant is aware, and will be revealed hereinafter.

I myself, as well as others have heretofore constructed highly successful airplanes equipped with longitudinal control means, operative thru the agency of adjusting the angle of incidence of the primary sustentation members or wings; in other language, wherein variations in the angle between the longitudinal axis of the fuselage and the trace of the plane of the wing chord on a vertical plane thru this longitudinal axis, are utilized for varying the lift coefficient of the wings, entirely independent of the presence or absence of any aerodynamic surfaces in the tails of the airplanes. Examples of such art have become known in United States Patents Numbers 1,856,093, 1,889,864 and 1,931,809.

However, all of the art up to the present time lacks something that impairs its perfection. The criterion in judging wing profiles that is regarded as of paramount importance is a combination of high maximum lift coefficient with low minimum profile drag. There is no known profile, and it seems improbable at the present time that a profile will soon be discovered, of constant geometric properties capable of combining very high

values of maximum lift coefficient with very low values of minimum profile drag. This places a limitation on airplanes designed with constant profile wings, even of the class wherein longitudinal control is accomplished by incidence adjustment, in spite of the otherwise excellent character of such airplanes, combining as they are well known to do, high efficiency, exceptional safety, and unusual ease of operation. Wings suitable for airplanes of this adjustable incidence nature, that are conducive to stable equilibrium of the airplane at any position of adjustment, have usually, by good fortune, a very low profile drag, but, unfortunately, none are known at the present time whose maximum lift coefficient attains very high values. On the other hand, there are known profiles having fairly high lift coefficients, but again, they are defective in having also a high value of minimum profile drag, as well as being impaired by possessing an excessive center of pressure travel between their low angle of attack condition and their high angle of attack condition, their centers of pressure being located far back away from the leading edge in the low angle condition, and fairly well forward in the high angle condition. This seriously handicaps them by requiring a heavy down load on the tail when an airplane employing a wing of such profile is in its cruising attitude, thereby inducing an unnecessary drag when it is most detrimental, and directly detracting from the pay load for any specific wing area, besides requiring a heavy structure to support the excessive internal loads. Even the best of the commonly used high lift profiles have lower values of maximum lift coefficient than are to be found in profiles modified by lift augmenters.

Heretofore, airplanes employing lift augmenters have been handicapped both in their safety character, and in their full efficiency by constructions based on a lack of appreciation of certain aerodynamic facts, recognition of which has enabled the present invention to overcome the imperfections, inefficiencies, and limitations of airplanes wherein an endeavor has been made to gain the benefit of lift augmenters.

It is an object of this invention to construct an airplane employing a lift augmenter, maintained inoperative at low angles of attack and brought into action only at high angles of attack.

It is a further object to construct an airplane wherein longitudinal control is secured by adjustments of the angle of incidence of the main wing or wings.

It is a further object to construct an airplane

of the variable incidence class, employing a lift augments, wherein adjustment of the incidence determines the angle of attack.

It is a further object to construct an airplane employing a lift augments wherein at any established angle of attack either with or without the lift augments being in action, the airplane will fly in stable equilibrium.

Other objects will appear from consideration of the ensuing description and reference to the annexed drawings, wherein:

Fig. 1 is a side elevation of an embodiment of the invention.

Fig. 2 is a side elevation of a wing of profile adaptable to the exercise of this invention.

Fig. 3 is a side elevation of the wing of Fig. 2, but provided with a trailing edge flap deflected down.

Fig. 4 is a diagram showing an analysis of forces acting on a wing of the profile shown in Fig. 2.

Fig. 5 is a diagram showing an analysis of forces acting on the wing of Fig. 3.

Fig. 6 is a diagram showing an analysis of forces acting on the wing of Fig. 2, modified at high angle of attack by deflecting the flap down as in Fig. 3.

Fig. 7 is a diagram showing the contour of a median line suitable for wings used in this invention.

Fig. 8 is a diagram showing two positions of flight of an airplane built according to this invention.

Fig. 9 is a view of a mechanism for carrying out the invention.

Fig. 10 is a diagram of a control system adaptable to this invention.

Fig. 11 is a fragmentary illustration of a fixed-wing adaptation of the invention, wherein longitudinal control is obtained by shifting the location of the center of gravity.

Fig. 12 is a fragmentary illustration of a fixed-wing adaptation wherein longitudinal control is obtained by an elevator in the tail.

Fig. 13 is a detail illustration of certain elements of Fig. 12, and

Fig. 14 is a detail of another element of Fig. 12.

In Fig. 1, an airplane is shown comprising a fuselage or body 1, upon which is secured by familiar means a chassis 2, a stabilizer 3, an elevator 4, a fin 5, a rudder 6, a tail skid 7, a power plant 8, and a propeller 9. A wing 10 is supported to body 1 by right and left front struts 11, equipped with pivotal supports 12 for angle of incidence adjustment. The wing 10 may be continuous across the body 1, or may be in right and left panels, which may, if desired, be differentially movable for roll control. Rear right and left struts 13 are vertically movable thru the medium of any suitable mechanism, such for example as that to be discussed hereinafter under Fig. 10. These rear struts 13 pass thru elongated openings 14 in body 1. The upper ends of struts 13 terminate in rock joints 15 in wing 10; and thus, the angle of incidence of wing 10 is adjustable by raising and lowering rear struts 13. The rear section 16 of wing 10 is separate from, and swingably mounted on wing 10 by hinges 17, thereby constituting what is commonly known as a trailing edge flap. It is at once apparent that in place of the trailing edge flap shown in Fig. 1, any one of a number of well known devices could as well be associated with wing 10. These devices come under the general classification of lift augments. Familiar examples in addition to those already suggested hereinbefore would include the Handley Page slots and flaps.

However, the common trailing edge flap as shown in Figs. 1, 2, 3, and 9 is readily constructed, and is useful in obtaining the results to be disclosed forthwith, but it should be clearly borne in mind that this invention is not restricted to any specific lift augments, and is adaptable to the operation of the generic device designated as the lift augments. Flaps 16 are swingably mounted on shafts 18 in hinges 17, and are actuated by cranks 19 equipped with pins 20, constrained to follow a definite path, as will be explained later, by the contour of cam slots 21 on body 1. In Fig. 1, stabilizer 3 is immovably secured to body 1, and elevator 4 is swingably secured to stabilizer 3 by means of shaft 22 and hinges 23. This arrangement is entirely satisfactory for certain embodiments of the invention, whereas for others, it is preferable to separate the right and left panels of the elevator 4, interposing stabilizer 3 between the right and left panels of the elevator 4, and constructing the elevator 4 as a spanwise continuation of stabilizer 3 when in a neutral position of adjustment, but with the right and left panels of elevator 4 synchronously movable in the same direction independently of stabilizer 3, which itself may be swingable under certain circumstances as will be disclosed hereinafter under Fig. 10. No drawing is offered here to illustrate the above described construction of the elevator spraddling the stabilizer, as it is not difficult to visualize from the preceding description assisted by the drawings as they stand.

A very important fact now presents itself. It is well known that lift augments have what has heretofore been regarded as detrimental characteristics, namely, they have a tendency to move the center of pressure toward the rear at high angles of attack as well as at low angles of attack, and the lift/drag ratio is lower than that of the corresponding profile when the lift augments are in its inactive position. Also, the center of pressure is always relatively far back at low angles of attack on all wings while influenced by lift augments, regardless of whether a wing is of the swingable type, to swing around an axis, such as at 12 in Figs. 1, 2, 3, 6, 8, 9, and 10, or a wing is of the rigid type represented in and by the diagrammatic illustrations of Figs. 4 and 5 as well as in Figs. 11 and 12. The first two of these characteristics combined, are put to useful service, and the last named is precluded as will be described forthwith. A mechanical device maintains the lift augments in its inactive position at low angles of attack. In Fig. 2, a wing 10 is flying at a low angle of attack W_L , the wing chord 24 forming a relatively small acute angle W_L with the flight path P . The lift augments 16 is in its neutral or inactive position, and wing chord 24 is a continuous, unbroken line from leading edge 26 to trailing edge 28.

In Fig. 3 the same profile is shown at a larger angle of attack, that is, with the chord 24 forming a relatively large acute angle W_H with the flight path P . Lift augments 16 is here shown in its operative position, its chord 25 inclined at an angle F to the wing chord 24.

Before proceeding to describe the mechanical means for causing the lift augments 16 to assume its neutral position at low angles of attack and its active position at high angle of attack, a discussion of the nature of the forces acting on the airplane will be offered.

The passage thru the air of an aerodynamic surface sets up certain reactions to its motion thru the air. An airfoil of a certain profile when

moving at a certain angle of attack will induce a reaction having a definite location and direction. For convenience in the study of aerodynamics, this reaction is commonly analyzed into two components, one perpendicular to the path relative to the air, and designated lift, the other parallel to this path and designated drag. The inclination of the line of action of the resultant reaction to this path is equal to $\tan^{-1} L/D$, where L and D represent simultaneous values of lift and drag respectively. The inclination of this line of action to the wing chord is equal to $\tan^{-1} L/D + W$, where W is the angle of attack. The line of action, inclined thus, intersects the chord of a wing at the center of pressure existent at the instant that the said simultaneous values of lift and drag are existent. In Fig. 4 a diagram is shown, indicating the various lines of action of aerodynamic reactions existing at various angles of attack; thus, the line designated 1° represents the direction and location of the line of action of the reaction existent when the wing is flying at 1° angle of attack. In Fig. 4, the chord 24 is shown, but the envelope profile, as shown in Figs. 2 and 3 is eliminated for the sake of avoiding confusion by the presence of too many lines. The intersection of any line of action, 1° , 6° , etc., with chord 24 is known as the center of pressure for the corresponding angle of attack. Such a diagram as that of Fig. 4 is best prepared by calculating the center of pressure location and the inclination of the corresponding line of action for each angle of attack that is to be investigated, using data obtained from a model, tested in the wind tunnel, and then drawing a line, inclined at the calculated inclination thru the calculated point of location of the center of pressure. In view of the fact that the technique of operating the wind tunnel is well known to those skilled in the art, no discussion of it will be included here.

It will be noted that beginning a short distance below chord 24, and extending as far down as the diagram is shown in Fig. 4, these lines of action progress consecutively from front to rear as the angle of attack is increased. If the center of gravity of the airplane be located on any line of action, and within the said region or zone below chord 24 in Fig. 4, the airplane will be in stable equilibrium as is well known to those skilled in the art. A symmetrical profile having the character shown in Fig. 4 may be prepared by proportioning its ordinates according to the equation:

$$\pm y = .2969\sqrt{x} - .126x - .3516x^2 + .2843x^3 - .1015x^4$$

as is well known to those skilled in the art. The profile shown in Fig. 2, and having the diagram of Fig. 4 is constructed from the above equation, but scaled down in thickness so that it has a maximum ordinate of $\pm 6\%$, or a 12% thickness at its thickest point, which occurs at 30% of the chord back from the leading edge 26. In the diagrams of Figs. 4, 5, 6, and 8, the wing chord 24 is shown with its leading edge 26 indicated by arrow points. An airplane constructed with a wing profile of the class just described, pivotally mounted for incidence adjustment is fully controllable, and at any adjusted angle of incidence, it will persist in flying in stable equilibrium at a definite angle of attack, as is well known to those skilled in the art.

However, if such a profile be modified by the trailing edge section being inclined downward as shown at 25 in Fig. 5, then the diagram shown

in Fig. 4 ceases to exist, and a diagram of entirely different nature shows the character of the so modified profile. Here, the lines of action 0° , 4° , etc., for an appreciable distance below the chord 24 progress from rear to front as the angle of attack is increased in the low angle range, and then, some distance below chord 24, they cross and progress from front to rear with increasing angles of attack in the high angle range, from about 12° up to the stalling point and even beyond. A wing of this nature, without the assistance of an auxiliary airfoil co-acting with it would not produce an airplane that could ever be in stable equilibrium, particularly with the center of gravity located on a line of action for less than 12° , and especially if the center of gravity were located up near the chord 24. Now, if the flap 16 of Fig. 3, deflected down at the angle F to the chord 24 were permitted to remain at the angle F , while the wing 10 attained a low angle of attack, such as W_L of Fig. 2, then such lines of action as -2° , 0° , 2° , 4° , etc., of Fig. 5 could come into existence. This is a serious imperfection in an airplane employing a lift augmenter, and wherein longitudinal control is effected thru the agency of deflecting a horizontal tail surface as the exclusive means, while the wing in such an airplane is of the rigid type with respect to the body of the airplane. This is especially true, if as has commonly been the case in prior constructions, the lift augmenter 16 is controlled by means of an independent manual means, for, even tho a wing having a concentrated center of pressure location such as that of Fig. 4 were to be employed, which has been suggested heretofore, its desirable character would be destroyed, and it would be necessary to use a stabilizer in the tail capable of exerting an excessive down load in the cruising range, and the pilot would be required to adjust this stabilizer simultaneously with adjustments of the lift augmenter. Also, in constructions that have been heretofore suggested wherein a manual means is provided that acts simultaneously on lift augmenter and stabilizer, increasing the deflection of the lift augmenter gradually while at the same time gradually inclining the stabilizer from its minimum position to its maximum position, most of the valuable diagram of Fig. 4 is lost.

In Fig. 6 there is a diagram showing the combined nature of a wing of the character shown in Fig. 4 wherein a lift augmenter, represented by its chord line 25 is maintained in neutral relation to the wing, represented by its chord line 24, thruout the low and medium angle of attack range, and yet is brought into positions of successively greater effectiveness as the maximum angle of attack is approached. Here, the chord 25 of the lift augmenter 16 of Fig. 2, hinged at 18 to the wing chord 24 is maintained in rectilinear relation to wing chord 24 while wing chord 24 is tipped about pivot 12 to vary its angle of attack from 1° to 14° . The center of gravity of the airplane, $C. G.$ lies on arc 27 and can be located on any desired line of action such as 2° as shown, by adjusting the angle of incidence of the wing chord 24 about pivot 12. The center of gravity $C. G.$, having been located by adjustment on any desired line of action, the airplane as a whole takes up a position relative to its path with reference to the air, such that the wing chord 24 is inclined to the path at the corresponding angle, for example, 2° as shown in Fig. 6. The airplane will now persist in flying at the angle of attack selected, because, as hereinbefore stated, the airplane is in

stable equilibrium at that angle of attack. When the 14° incidence is exceeded, mechanism provided will automatically deflect flap chord 25. Thus, at 16° angle of incidence flap chord 25 assumes position A, and the line of action for this combination is 16°a. Further increase in incidence to 18° deflects flap chord 25 to position B, and at the same time shifts the relative position of the center of gravity C. G. along arc 27 to a position on the newly created line of action 18°b. In designing this airplane, care is exercised to locate the fore and aft position of pivot 12 on wing 10, and the height of pivot 12 above the center of gravity C. G. of the complete airplane so that the angle of incidence change to move the center of gravity C. G. relative to the wing chord 24 is equal to, or at least nearly equal to the angle of attack change corresponding to the lines of action between which the center of gravity C. G. has been relatively moved. In Fig. 6, a combination is shown wherein further incidence change to 19° associated with the increased deflection of lift augmenter 25 to position C, establishes line of action 19°c, and the distance between line of action 18°b and 19°c along arc 27 is practically zero, whereas the distance traversed by the center of gravity C. G. along arc 27 while rotating wing chord 24 thru the difference in angle of attack in question, namely 1° would not be essentially zero. This would mean that the center of gravity would now lie to the right of line of action 19°c on arc 27. This brings up a new action. With the wing chord 24 and the flap chord 25 adjusted in combination to establish line of action 19°c, the airplane will be out of balance, and a stalling moment will exist, because the relative location of the center of gravity C. G. will be to the right of line of action 19°c. The construction that compensates for this will be discussed presently by the aid of Fig. 8.

So far, the profiles shown herein are of the symmetrical class. Expressed otherwise, their median lines have been rectilinear. This is not essential, as there are many asymmetrical forms that have excellent properties. An example of these could be prepared by forming a median line according to the equation:

$$y = hx(1-x)(1-.875x)$$

as is well known to those skilled in the art. Figure 7 shows such a median line with the coefficient h adjusted to bring the maximum ordinate to a value of 6% of the chord. Here, the chord 24 is used as the axis of abscissae, and the median line 28 is derived from the above equation. It will be noted that median line 28 crosses chord 24 at point 29, which is located 87.5% back from leading edge 26. To construct a wing profile according to this form, the envelope, which may be one derived from the equation on page 3, line 55, is superposed on the median line just described in a manner well understood by those skilled in the art. This invention does not necessarily feature the specific profiles just described. They are offered as definite examples to illustrate the nature of one of the features of the invention. Any profile showing a diagram similar to that of Fig. 4 will serve as a basis for this invention, and if a test in the wind tunnel shows a profile of unknown contour to have the character of the diagram of Fig. 4, then the unknown profile would be entirely satisfactory as a nucleus for the exercise of this invention. Also, in a diagram like that of Fig. 4, the wing chord 24, and the pivot 12 of Fig. 1 may be located relative to the center of gravity

C. G. of the airplane such that the center of gravity C. G. lies constantly at or approximately at Q, or a constant distance from leading edge 26 in Fig. 4, and with the assistance of the stabilizer 3 of Fig. 1, incidence variation is feasible, and yet the airplane can be maintained in stable equilibrium, because it would be in neutral equilibrium or else in a state of unbalance with a constant upsetting moment without the assistance of the stabilizer, whereas the stabilizer 3 comes into action here, not merely to restore balance as is commonly understood by those skilled in the art, but to offer a righting moment whenever the airplane departs from the angle of attack for which it has been adjusted. So long as the progression of the lines of action is not definitely from rear to front with increasing angles of attack, a practicable airplane may be constructed using variable incidence for longitudinal control.

In Fig. 8 a diagram is shown analyzing two conditions of flight of an airplane embodying this invention, namely medium angle of attack with a lift augmenter in its neutral or inactive position, and high angle of attack with the lift augmenter fully effective. In this figure, the lift augmenter 30 is a thin plate, depending from the trailing edge 31, and perpendicular to the chord 24. The nature of a lift augmenter of this class is well known to those skilled in the art. Assume that the airplane being analyzed in Fig. 8 is flying at M° angle of attack, M being well above the angle of zero lift and somewhat below the stall. Under these conditions, the airplane is following path P_M relative to the air. The airplane of Fig. 8 is provided with a fixed or non-adjustable stabilizer, represented by its chord 3, its envelope being omitted from the figure. The elevator 4 of Fig. 1 is absent. When flying thus at M° angle of attack, with the parts of the airplane so proportioned that the sum total of moments extraneous to those induced by the wing 24 is zero, the line of action 32 of the reaction corresponding to M° then passes thru the center of gravity C. G. of the airplane. The stabilizer 3 in this case is set at its angle of attack for zero lift relative to the path P_M. The stabilizer 3, then, while the airplane is following path P_M is ineffective and has little if any influence on the attitude of the airplane. Its reaction is directed parallel to path P_M and backward in its direction. It could as well be absent, as the airplane is in stable equilibrium at M° angle of attack as explained hereinbefore in discussing Figs. 4 and 6. The pilot now adjusts lift augmenter 30 into its effective position as shown by the dotted line 30. It should be noted here that when the airplane was flying at M° angle of attack, only such lines as appear full were to be considered. Dotted line 30 was to be disregarded as though it were absent. Now, with dotted line 30 present, representing the effective presence of the lift augmenter, line of action 32 ceases to exist, and instead line of action 33 is created. Line of action 33, passing forward of center of gravity C. G. induces a stalling moment, and the airplane is momentarily out of balance, and as a result rotates about its center of gravity C. G. until its relative path is the dotted line P_H, inclined at angle 34 to old relative path P_M. It may be that P_M and P_H both lie on the same line relative to the earth, or it may be that they do not. That depends upon determining factors that need not be considered here, such as engine thrust. P_M might represent level flight and P_H climb, or various other combinations. The stabilizer 3 has a positive angle of attack because it is positively inclined to-

ward new path P_H , and therefore its newly established reaction has a new line of action 35 with an upward component, and is not any longer parallel to the path P_H . Reaction 35 exerts a driving moment about center of gravity C. G. that balances and offsets the stalling moment of wing reaction 33. The moment arm 37 of reaction 33 multiplied by the magnitude of reaction 33 is equal to the moment arm 36 of reaction 35, multiplied by the magnitude of reaction 35. Thus, with the assistance of stabilizer 3, the airplane is again in equilibrium. It is in stable equilibrium, because, any disturbance that causes an angular displacement of the whole airplane relative to its path will in so doing cause a new reaction on the stabilizer 3, which not only compensates for the movement of the line of action of the wing, but overbalances it, and tends to return the airplane to the established angle of attack, as is well known to those skilled in the art. We have in effect, with the construction disclosed in Fig. 8, at any established value of angle of attack in the high angle range, with the lift augments 30 in action, a conventional airplane with its stabilizer set at an excessively high degree of decalage. With lift augments 30 in action, the diagram of wing reactions is similar to that of Fig. 5, but, as just explained, it is corrected by stabilizer 3, producing a diagram for the whole airplane that bears a resemblance to the diagram of Fig. 4. Thus, in such a construction, the lift augments is ineffective at low angles of attack which are established for the airplane, and, the airplane being in stable equilibrium from the action of the wing alone, stabilizer 3 is unessential, and merely rides in a neutral and ineffective position; but when the lift augments 30 is brought into use at high angles of attack which are established for the airplane, stabilizer 3 becomes necessary, and automatically comes into action, thru the agency of the unbalance of the airplane tipping it as a whole, and thereby presenting the stabilizer 3 to the air at an effective angle of attack. This leads to the presentation of another advantageous feature of the present invention. The purpose of establishing a high angle of attack in an airplane is to raise the value of the lift coefficient to a high figure, generally for maintaining level flight at a minimum speed, or to secure a favorable landing condition. In an ordinary airplane controlled by an elevator, in order to secure a minimum speed along the path, high angle of attack is attained by reducing or even reversing the direction of the tail load, so that it is either low, or else negative relative to that of the wing. Therefore, any assistance that might be desired from the empennage in assisting in sustaining the airplane, at the time when such sustentation is most needed, must be sacrificed. This sacrifice may be regarded as a serious defect. In the airplane analyzed in Fig. 8, the horizontal tail surface 3 is at its most effective lifting condition at maximum established angle of attack, assisting in the attainment of extremely low speeds for landing. This results from the greatly reduced L/D ratio with the lift augments in action at high angles of attack, which more than compensates for the rearward location of the center of pressure by causing the inclination of the line of action to possess a relatively large forward component. This forward component becomes increasingly effective as greater distances are selected below the pivot point 12, of Figs. 1, 2, 3, and 6, for the locus of the center of gravity of the airplane. Thus, it is clear that in the airplane analyzed in Fig. 8, not only are the advan-

tages hereinbefore described retained, but in addition, valuable assistance is offered by the tail to increasing the maximum lift on the airplane at high angle of attack, and at low angle of attack there is no sacrifice in the form of a down load on the tail.

In Fig. 9 two positions of a wing with a lift augments are shown to elucidate the operation of one form of mechanism for the exercise of this invention. A low angle position is shown in full lines, and a high angle position is shown in dot and dash lines. A support 11, such as a strut of Fig. 1, or other suitable element in a fuselage 1, swingably supports a wing 10 about a shaft 12, permitting it to move from a low angle position 10L to a high angle position 10H. A mechanism, not shown here, but which might very well be that which will be explained later under Fig. 10, enables the pilot to move the wing 10 from 10L to 10H at will. At a suitable position forward of the trailing edge 38 of wing 10 hinges 17 are provided, to support shaft 18 for swingably supporting lift augments 16. A crank 19 is secured to lift augments 16 in a manner such that a constant angular relation between crank 19 and lift augments 16 always prevails. Crank 19 is secured preferably in rigid relation to shaft 18 for this purpose, shaft 18 being an integral part of lift augments 16. Crank 19 terminates in pin 20, or other suitable cam follower, the design of which is well understood by those skilled in the art. A rigid member 58 is secured to any suitable part of the structure of fuselage 1 in Fig. 1. Member 58 is provided with a slot 21 engaging cam follower 20. Slot 21 is formed with its center line 39 a circular arc having the center of shaft 12 as its center thruout the low and medium angle of attack range for wing 10, and departing from this circular arc 39 with an increasing component of deviation toward shaft 12. The action of this device is as follows: Assume wing 10 at low angle adjustment 10L. Lift augments 16L, supported by hinges 17L and shaft 18L is in its neutral position, and is constrained to remain so by crank 19L, positioned by cam follower 20L, engaged by slot 21. The pilot increases the angle of attack until wing 10 is at 10H. This pushes shaft 18 down, carrying with it crank 19. Slot 21, by its contour, constrains follower 20 to move from 20L to 20H, bringing crank 19 to 19H, shaft 18 to 18H, and lift augments 16 to 16H as shown in the dot and dash lines. Thus, by a proper proportioning of slot 21, any desired progression of lift augments 16, from its neutral position 16L to its fully active position 16H may be obtained. For example, if it were desired to retain lift augments 16 in neutral until the maximum angle of attack for wing 10 was nearly attained, the departure from the circular arc 39 with shaft 21 as its center, would be delayed, and perhaps departing along a radius toward center 21. When the axis of crank 19 lies near or coincident with a line joining the centers of shafts 12 and 18, small changes in angular movement of wing 10 cause large angular changes in lift augments 16.

Fig. 10 shows a mechanical device suitable for the exercise of this invention in certain of its features. The wing 10, pivoted at a suitable point on shaft 12 hung in support 11, which may be strut 11 of Fig. 1, or any other suitable mounting is swingable to alter its angle of incidence, or in other words, the angle between its chord and the axis of fuselage 1. A strut, link, or other appropriate device 13 is pivoted at 15 to wing 10. The other end of strut 13 is pivoted at 40 to bell 75

crank 41, which is fulcrumed at 42 to a bracket 43 secured to any suitable portion of the structure of fuselage 1, Fig. 1. The other leg of bell crank 41 is provided with slot 44 in which pin 45 is engaged. Pin 45 is secured to push-pull rod 46, threaded on one end 47 to receive threaded hand wheel 48, rotatably retained in bracket 49, which is secured to some suitable portion of fuselage 1, Fig. 1, and is readily accessible to the pilot. The other end of rod 46 is provided with a key, spline, square, or other restraint against rotation 50, associated with slide 51 which is secured to any appropriate part of fuselage 1, Fig. 1. Beyond slide 51, rod 46 terminates in a fork 52, located near the tail of the airplane. A pin 53 is adapted to engage fork 52, and is secured to crank 54, which is rigidly secured to shaft 55, articulated in bracket 56. Bracket 56 is secured to a suitable member in the tail of fuselage 1, Fig. 1. Shaft 55 is an integral part of a horizontal tail surface 57. The operation is as follows: The pilot turns hand wheel 48 in a certain direction, which pulls rod 46 and pin 45, pin 45 thereby moving bell crank 41. Slot 44 accommodates the relative vertical movement between bell crank 42 and pin 45, avoiding jamming of the parts. Forward movement of slot 44 induces upward movement of pin 40, thereby pushing strut 13 upward, and resulting in an upward shifting of the trailing edge 38 of wing 10. By virtue of being pivoted at 12, the said upward movement of pivot 15 decreases the angle of incidence of wing 10. Simultaneously with this action, the forward movement of rod 46 pulls fork 52 out of engagement with pin 53, allowing full free floating of flipper 57, to assume a zero lift angle of attack at all times. Key 50 sliding in slide 51 permits free axial movement of rod 46 but prevents rotation. Movement of hand wheel 48 in the opposite direction induces movement of the various parts in counterdirection, increasing the angle of incidence of wing 10, and locking flipper 57 in a fixed position. If desired, instead of such a fork as that shown at 52, some other shape could as well be made, for example, instead of the inner faces being straight lines as shown, they could be straight converging lines for a certain distance, and then their direction change so that they terminate in parallel lines of just sufficient distance of separation to constrain pin 53 against swinging movement, thus maintaining flipper 57 as a fixed surface thruout a range of angular movement of wing 10. Various contours could also be applied to the constraining member in substitution for fork 52, causing flipper 57 to assume a certain angle of attack for a certain wing setting, and other angles for other settings of wing 10.

While nothing is shown in Fig. 10 in the way of a lift augments, or operating means therefor, it is evident that such a device as that of Fig. 9 or any other desirable device of such nature could readily be associated with the device of Fig. 10.

In view of the fact that angle of attack variation is a means of speed control, the locking of tail surface 57 may be regarded as dependent on established speed; and also lift augments adjustment may be regarded as being dependent on established speed.

Many mechanical devices are useful for operating the airplane, according to this invention, and the incidence variation as well as the operation of the lift augments and the locking of the tail surface may be as well accomplished by pneumatic, hydraulic, or electrical means rather than by linkages or gears.

The mechanical means, however, are immaterial, or, at least, are not meant to be stressed in detail claims, as long as it is understood that a maximum lift coefficient at a high angle of attack is the result to be obtained, and when stressing the high angle of attack it should at the same time also be clear and understood that this is not at all necessarily to include a high angle of incidence of the general conception.

This is perhaps best made clear by referring to a variation of general construction over what has been set forth above with reference to the illustrations of Figs. 1, 2, 3, 9 and 10.

It should be clear from what has been explained above with reference to the illustrations in Figs. 4 and 5 in particular, but also with reference to the illustrations in Figs. 6, 7, and 8 in general, that the principal feature of this invention is equally well applicable to various and distinct forms of airplane constructions.

One of such different or distinct constructions is outlined in Fig. 11, involving the well known general principle of shifting the location of the center of gravity.

In this illustration of Fig. 11, however, this otherwise well understood principle is made applicable to the principal feature of the present invention by operatively connecting the variable gravity feature to the lift augments control feature of the present invention.

As illustrated, the wing 10 of the general character of Figs. 4, 5, and 6 is here rigidly mounted on the body 1 of an airplane, while the augments 16 is pivotally mounted at 18 by means of the hinge or support 17 on the wing in a similar manner as in the forms illustrated in Figs. 1, 2, 3, and 9.

A weight 119, suitably heavy to control the gravity of an airplane is movably mounted on the member 118, held against rotation by the member 60 on the supports 61, 62, and 63, the member 118 being turnable by the motor 64, whereby the shifting movement of the weight is procured in such a manner as to vary the location of the center of gravity of the whole airplane on which this mechanism is provided.

For operating this gravity control, leads 65 and 66 with the terminal contacts 67 and 68 can be brought into a circuit by means of the switch 69 through the leads 70, 71, and 72, a battery 73 being indicated as a motive force grounded by means of the lead 74 to the supporting member 60. Distinct and independently operating solenoids 75 and 76 are provided to act on a common member 82, connected by link 83 to the lift augments 16 at 84.

While the lead 72, coming from the battery 73, connects to both solenoids 75 and 76, a separate lead 77 connects with the one solenoid 75 and another separate lead 78 connects with the other solenoid 76. The opposite end of the lead 77 connects with the contact bar 79, and the opposite end of the lead 78 connects with the contact bar 80, a contact-making piece 81 being provided on the weight 119 whereby the circuit is closed as the weight moves along the member 118 through either the bar 79 or the bar 80.

The solenoid 75 is designed so that the augments 16 is held steadily in neutral or inoperative position, as far as any undue lift-augmenting is concerned, as long as the circuit is closed through the bar 79; while the solenoid 76 is designed to cause a downward tilting of the augments 16 whenever the circuit is closed through bar 80.

A changing of the location of the center of gravity in the whole airplane by means of the movements of the weight 119 causes the airplane to assume a corresponding angle of attack, and at any change of angle of attack the augments 5 is automatically adjusted to the corresponding position with due regard to a maximum lift coefficient if designed in agreement with the principles of this invention.

10 Another of such different and distinct constructions is outlined in Fig. 12, with details in Figs. 13 and 14, the illustration in Fig. 12 involving the well known general principle of longitudinal control by means of an elevator at the tail 15 end of the airplane, particularly involving the Handley Page slots and flaps arrangement, referred to in lines 74 and 75, page 2.

In Fig. 12, wing 10 is not necessarily of the specific character repeatedly described, but may be 20 of any character, the wing being, nevertheless, rigidly mounted on the body 1. Augmenter 16 is mounted similarly as in the other forms, but in this case provided with an extension or lever portion 100 with a pin 101, connected by the rod 25 102 with the piston 117 in the cylinder 103, mounted on the support 104, the rod having collars 110 and 111 for actuating the shutter 108 by means of the portion 109. The shutter 108 serves to control a leading-edge slot 107 in the wing 10. 30 A spring 116 is inserted in the cylinder to counteract on the piston when the pressure is released for returning the piston to neutral position.

An elevator 4 is swingably mounted in the tail end of the airplane on a shaft 22, which is in this 35 case provided with a hollow 85. This elevator is provided with a device, variously designated as a "tab", "pilot vane", or "flettner flap" 86, mounted by means of pin 87 and support 88.

Tab 86 is provided with an extension or lever 40 portion 89 with a pin 90, connected by rod 91 to piston 114 in the cylinder 92, having a spring 113 inserted to counteract the pressure in this cylinder, the cylinder being mounted on the support 93.

45 A two way valve 96 is provided with a handle 97, located within easy access of the pilot of the airplane. A pressure reservoir 98 serves to supply the motive force or pressure. Raising the handle 97 operates the valve 96 to pass the pressure 50 into the line 95, and lowering the handle releases the pressure through the outlet 99.

The applied pressure passes through the line 95, into the branch 105 with the flexible portion 106 55 as well as into the flexible portion 94 in the hollow shaft 22. The flexible portions serve to take care of vibrations and movements of the cylinders, the portion 94 being extended into the shaft 22, which, of course, must be free to turn, and terminates by way of the orifice 115.

60 When pressure is thus applied, spring 113 offering less resistance than spring 116, being particularly proportioned in this manner, rod 91 moves out, tipping "tab" 86 down, which acts aerodynamically in a well known manner to establish 65 the angle of incidence of elevator 4, which in turn reacts aerodynamically to establish the angle of attack of the wing 10, or, in this case of the whole airplane, relative to its path until for any particular setting of "tab" 86 stable equilibrium is established at a definite angle of attack 70 at which the airplane persists in flying until "tab" 86 is again adjusted.

Throughout a predetermined incidence range for the elevator 4, spring 113 and the pressure 75 from the reservoir 98, controlled by valve 96, have

no other effect than to come to balance with piston 114 somewhat between its two extremes of movements.

However, when spring 113 has been fully compressed by the pressure upon the piston 114, it 5 acts as a stop to prevent further movement and lets the pressure build up as the handle 97 is further actuated until the pressure is sufficient to overcome the resistance of spring 116, thereby actuating rod 102, causing augmentor 16 10 to assume an active position, as well as opening shutter 108, bringing slot 107 into action.

Of course, either slot 107 or augmentor 16 could be eliminated without interfering with the action 15 of one or the other as will be clear to those skilled in the art, but the combined action of the slot and the augmentor is readily accomplished by the described means, and this combined action is well known to be very efficacious as a lift augmenting means referred to in the beginning of 20 the description with reference to Handley Page slot and flap.

From the above it should be understood that a lift augmenting device designed and arranged 25 according to this invention can be made to raise the value of the lift coefficient above a maximum at a high angle of attack of a wing. On the other hand, a hydraulic cylinder and piston could be substituted for the bell crank 41 of Fig. 10, which, 30 when a predetermined value of angle of incidence is attained, comes to the end of its stroke, and at the same time opens a valve communicating with another hydraulic cylinder associated with crank 19. Thus, control movements by the pilot could 35 be made to increase the incidence up to a certain point, and then, further hand movements would bring lift augmentor 16 into increasingly operative positions.

The mechanical device shown in Fig. 10, but 40 with members 52, 53, 54, and 56 eliminated, and stabilizer 57 immovably secured to anchor 56 by any well known means, is adaptable to another feature of the invention. If a wing of the character of Fig. 4 were mounted with point 59, where 45 the lines of action 1°, 8°, 14° etc. all converge and substantially all intersect each other on the center of gravity of the airplane, and if the pivot 12 were also located at or substantially at this same point, 59, then variations in the incidence of 50 wing chord 24 would not disturb the balance of the airplane, and variations in angle of attack due to changes in the attitude of the airplane relative to its path would likewise not disturb the balance of the airplane. The airplane would be 55 in equilibrium at any position of incidence adjustment, but it would always be in neutral equilibrium. The addition of a fixed stabilizer in the tail of the airplane would readily correct this and put the airplane in stable equilibrium, because, the stabilizer would carry neither an up nor a 60 down load normally, but the slightest deviation from a neutral position would create a relatively heavy restoring moment even though a small area of tail were used.

It is manifest that numerous variations in detail 65 could be made, and yet accomplish the same results as the specific devices shown and described hereinbefore. Therefore, the spirit rather than any specific details as shown should be construed as constituting the present invention. 70

It should finally be understood that, when the principles of this invention are applied to various distinct forms of airplanes or airplane constructions, it is most positively not so much concerned 75

about any change of incidence, though incidentally a change of incidence may become involved, but rather the change of angle of attack controllable by and causing control of other auxiliary means whereby any changing of attack beyond a certain acute point makes any sort of airplane more efficient and more safe, by, particularly, making it impossible that the augmenting device can be brought into play or into action before the airplane has been operated through a considerable movement from a low angle of attack to a certain acute point of the whole range of movements towards a high angle of attack, involving that a plane must be operated from a low angle of attack, regardless of the direction, whether in level flight, rising, or landing direction, to a suitable higher angle of attack beyond the danger or acute point, or beyond the danger zone of the movements for changing from a low to a high angle of attack up to the acute point, before the augmenting device can be brought into action.

Having described my invention, I claim:

1. In an aircraft having a body, a wing pivotally mounted on said body about a pivot in the forward part of the wing and comprising a main wing section and a trailing edge flap pivoted on said main section for movement with respect thereto, mechanism to positively swing said wing about its pivotal mounting, a control member secured to said flap, said body having guide means comprising one portion concentric with the pivot of the wing and another portion non-concentric therewith, said portions cooperating with said control member whereby the flap is held in alignment with the said main section during the first portion of the downward pivotal movement of the wing from its normal setting on the body and is displaced downwardly relative to the main section throughout the remainder of the downward pivotal movement of the wing.

2. In an aircraft with a wing operative by means for changing the angle of attack throughout distinct primary and secondary ranges during a normal flight designed and arranged to create a normally maximum lift coefficient at an effective high angle of attack and including a lift augmenting device movably mounted on the wing, the primary range including all positions between the lowermost up to the highest low angle of attack, and the secondary range including all positions above said highest low up to the highest high angle of attack in which a normally maximum lift coefficient is effective; a control device disposed on the aircraft and in operative connection with the lift augmenting device having control-means for the primary range whereby the lift-augmenting device is maintained inoperative and including distinct other control-means for the secondary range whereby the lift-augmenting device is brought into action with an increase above said normal maximum lift coefficient.

3. In an aircraft with a wing operative by means for changing the angle of attack throughout distinct primary and secondary ranges with respect to a normal flight direction designed and arranged to create a normally maximum lift coefficient at an effective high angle of attack and including a lift augmenting device swingably mounted on the wing, the primary range including all positions from the lowest angle up to a point in which the lift coefficient has values between 40% and 99% of said maximum, and the

secondary range including all positions above said point up to the highest high angle of attack in which a normally maximum lift coefficient is effective; a control device disposed on the aircraft and in operative connection with the lift augmenting device having control-means designed for continuance-positioning for the primary range whereby the lift augmenting device is automatically maintained inoperative by the operation of the wing during said primary range and including distinct other control-means designed for variable-positioning whereby the lift augmenting device is automatically brought into action by the operation of the wing during said secondary range with an increase above said normal maximum lift coefficient.

4. In an aircraft embodying a wing with a lift augmenting device and including operating means by which the angle of the wing chord to the path of the air stream can be changed to the extent of distinct primary and secondary ranges during the normal flight of the aircraft, the primary range including all positions between the lowermost up to the highest low angle, and the secondary range including all positions above said highest low up to the highest high angle; a control device disposed on the aircraft and in operative connection with the lift augmenting device having distinct control means for the primary range whereby the lift augmenting device is maintained inoperative and including other distinct control means for the secondary range whereby the lift augmenting device is brought into action with an increase of the lift coefficient of the aircraft.

5. In an aircraft with a center of gravity and a wing of the class described wherein the lines of action of aerodynamic reactions progress consecutively from front to rear throughout the flying range at a level of the center of gravity of the aircraft and including a lift augmenting device whose action modifies the progression of said lines of action, said range constituting distinct primary and secondary portions, the primary portion including all positions between the lowermost up to the highest low angle, and the secondary portion including all positions above said highest low up to the highest high angle; a control device disposed on the aircraft and in operative connection with the lift augmenting device having distinct control means for the primary portion whereby the lift augmenting device is maintained inoperative and including other distinct control means for the secondary portion whereby the lift augmenting device is brought into action, and an auxiliary aerodynamic surface secured to the aircraft in longitudinal spaced relation to the wing designed and arranged to exert a moment about said center of gravity while said augmenting device is in action and to exert no moment about said center of gravity when said lift augmenting device is maintained inoperative.

6. In an aircraft with a wing operative by means for changing the angle of incidence during a normal flight in such a manner as to also change the angle of attack in form of distinct primary and secondary ranges and arranged to create a normally maximum lift coefficient at an effective high angle of attack, the primary range including all positions between the lowermost up to the highest low angle, and the secondary range including all positions above said highest low up to the highest high angle; an auxiliary aerodynamic surface in longitudinally spaced

relation to said wing mounted to swing freely on the aircraft and having a control means, and a mechanism in operative connection with the means operating the wing including a locking member so designed and arranged as to leave said control means and therewith the auxiliary surface free to swing while the aircraft is within said primary range and to firmly engage the control means for holding said surface in predetermined fixed relation to the aircraft within said secondary range.

7. In an aircraft with a wing operative by means for changing the angle of incidence during a normal flight in such a manner as to also change the angle of attack in form of distinct primary and secondary ranges serving as a speed controlling means and arranged to create a normally maximum lift coefficient at an effective high angle of attack, the primary range includ-

ing all positions between the lowermost up to the highest low angle suitable for high speed, and the secondary range including all positions above said highest low up to the highest high angle appropriate for low speed; an auxiliary aerodynamic surface in longitudinally spaced relation to said wing mounted to swing freely on the aircraft and having a control means, and a mechanism in operative connection with the means operating the wing including a locking member so designed and arranged as to leave said control means and therewith the auxiliary surface free to swing while the aircraft is within said primary range and furthermore so designed and arranged as to firmly engage the control means for holding said surface in predetermined fixed relation to the aircraft within the secondary range.

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