

June 16, 1931.

H. ALFARO

1,810,693

AEROPLANE

Filed March 7, 1928

2 Sheets-Sheet 1

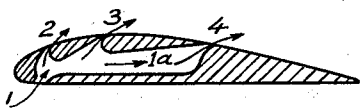


Fig. 1

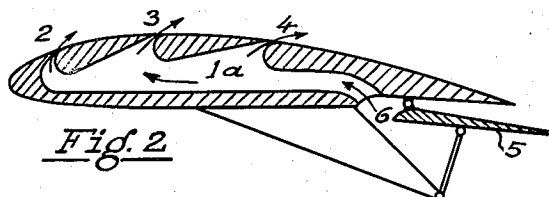


Fig. 2

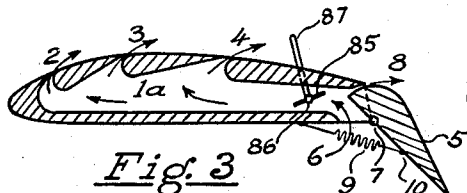


Fig. 3

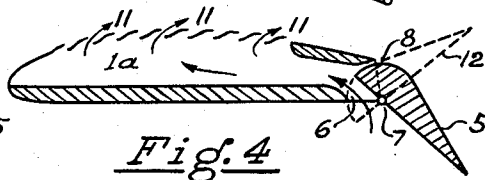


Fig. 4

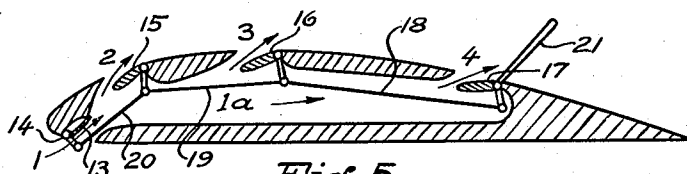


Fig. 5

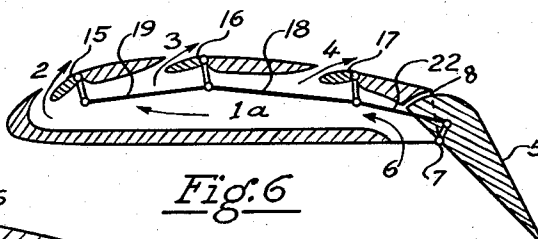


Fig. 6

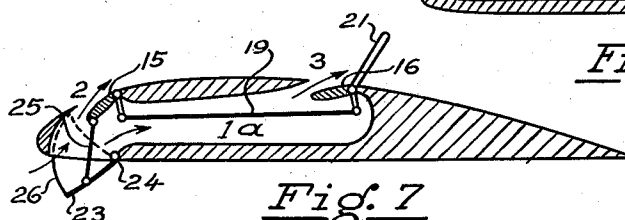


Fig. 7

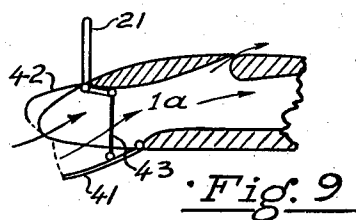


Fig. 9

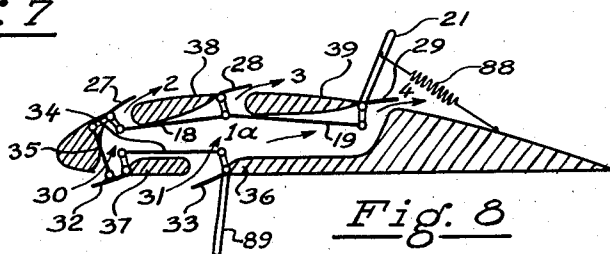


Fig. 8

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2 Sheets-Sheet 2

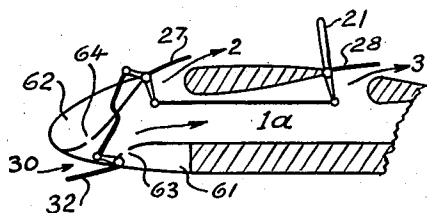


Fig. 11

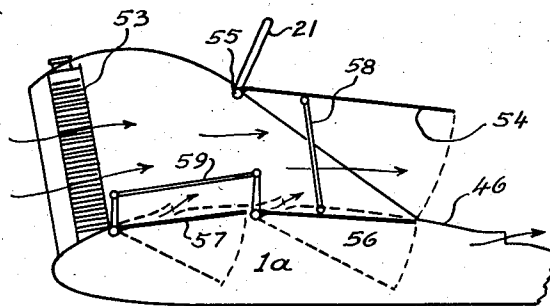


Fig. 10

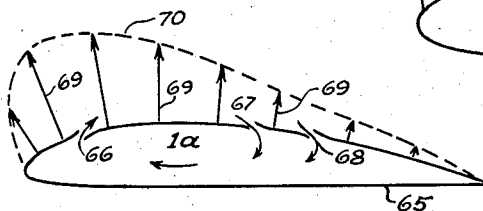


Fig. 12

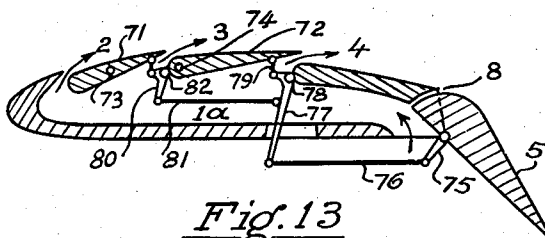


Fig. 13

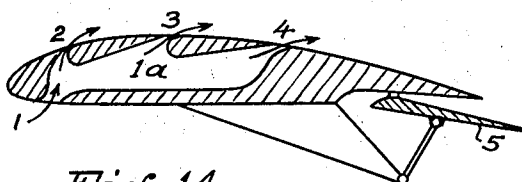


Fig. 14

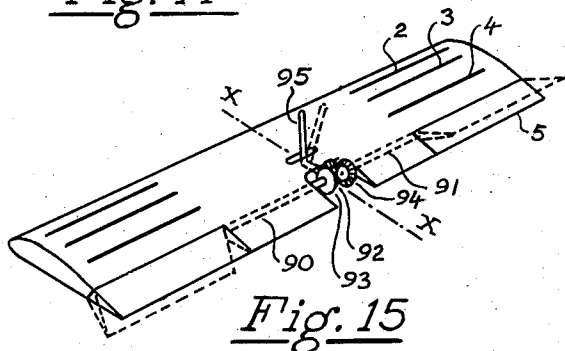


Fig. 15

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UNITED STATES PATENT OFFICE

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AEROPLANE

Application filed March 7, 1928. Serial No. 259,811.

This invention relates to aeroplanes, and more particularly to aeroplane wings and aeroplane control surfaces, and has for its object to provide advantageous means for
5 increasing the lift of aeroplane surfaces.

Aeroplane wings give more lift at higher angles. The geometric angle at which most wings give their maximum lift varies usually from 15 to 20 degrees. At higher angles, the lift in some cases decreases gradually and in others breaks down suddenly to a smaller figure. In control surfaces, formed either by a rigid unit or by a plurality of articulated parts, the action is much the same, the lift
10 decreasing with any increase in the angle beyond that of maximum lift.

Special wing constructions have been devised in which the angle of maximum lift is increased and in which a higher maximum
20 lift is obtained than with the usual type of wing. Some of these special wings obtain the increase of lift by the use of a flap near the trailing edge. This result may also be obtained by the combined motion of rotation and translation of a flap as described in my
25 copending application Serial No. 236,342, filed Nov. 28, 1927. In some instances, an increase of lift is obtained by the action of a slot near the leading edge with the resulting
30 change of flow around the airfoil, and in other instances, the combination of a leading edge slot and a trailing edge flap is used.

Nearly all of these devices require the operation of a controlling mechanism which
35 demands a considerable physical effort on the part of the pilot for its operation, and, in addition, they necessitate a certain increase in the weight of the lifting units. Furthermore, these devices offer a greater drag or
40 head resistance tending to reduce speed even when the lift increasing mechanism is not in operation. Also, some of these mechanisms require, for the maximum lift, an angle of attack which is difficult to obtain in normal
45 operation of the aeroplane, and especially in landing.

In wind tunnel tests, great increase of lift has been obtained by releasing compressed air on the suction side or upper face of an
50 airfoil. The possible objection of this

scheme when applied to full size aeroplanes is the difficulty of obtaining efficiently a sufficient amount of compressed air to improve the lift. In similar tests, it has been found that, with the proper arrangement of openings in the suction side of an airfoil, it is more efficient for increasing the lift, to suck air in, rather than to blow it out.

An object of this invention is to obtain an increase of the maximum lifting capacity of wings efficiently and without additional apparatus.
60

Another object is to provide the necessary means within a reasonable amount, if any, of additional weight.
65

A third object of the invention is to avoid early stalling of aeroplane wings, to provide a high maximum lift, and to maintain a high value of lift throughout a relatively wide range of angles of attack without sudden
70 breakages of said lift value.

Still another object of my invention is to provide a lift increasing means which is simple in operation and which requires little effort on the part of the operator.
75

Another object is to provide said maximum lift at relatively low angles of attack which the flying machine can easily be brought into.

Other objects of the invention are to obtain better lateral control by providing better aileron control at low speed and to obtain better rotational stability.
80

Other objects will be apparent to those skilled in the art from the description of it hereinafter given.
85

Figs. 1, 2, 3 and 4 show in transverse section, different forms of airfoils embodying the invention.

Figs. 5, 6, 7 and 8 are sectional views showing wing structures embodying the invention in which means is provided for controlling the openings in the wings through which the air passes.
90

Fig. 9 is a fragmentary transverse section showing an air collector or scoop in connection with the air inlet openings.
95

Fig. 10 is a side elevation showing a modification of the invention in which air which has passed through the radiator is directed
100

into the wings and out through openings in the suction side thereof.

Fig. 11 is a fragmentary section showing a modified form of the invention utilizing
5 heated air.

Fig. 12 is a diagrammatic view illustrating a further modification of the invention in which both the inlet and outlet openings are in the upper or suction side of the air-
10 foil.

Figs. 13 and 14 are sectional views showing further modifications of the invention.

Fig. 15 is a perspective view showing a complete airfoil provided with aileron control.
15

I have found that by providing certain passages of air from the lower face or pressure side to the interior of wings and by providing other properly placed passages on the
20 upper face or suction side of said wing as air exits, the flow of air around said wing can be so controlled as to considerably increase the lifting capacity of the wing.

Moreover, I have found that by combining
25 the action of a flap with that of the above mentioned passages, as illustrated in Figs. 2, 4, 6, 13 and 14 of the drawings, a greater amount of air can be released through the suction side exits and a lower angle of maximum lift can be obtained.
30

Also, I found it advantageous to locate the intake passages at the points on the wing where the air pressure is highest, so as to obtain a maximum flow of air.

Furthermore, by controlling the intake and exit openings, as illustrated in Figs. 5, 6, 7, 8, 9 and 13, the increase of lift provided thereby can be utilized when desirable and at other times, the drag or head resistance tending
40 to reduce speed can be reduced by shutting the openings. I have found, also, that the control of these openings may serve to increase the efficiency of lateral control of the wings and to reduce rotational instability,
45 usually referred to as spinning.

It is known that in the plain type of airfoil, the flow becomes irregular and turbulent on the suction side of the airfoil as the angle of attack approaches that of maximum lift.
50 Such irregular flow does not follow any more the contour of the upper face of the wing but detaches itself from said surface so that increased downward deflection of the air cannot be obtained by further increase in the
55 angle of attack of the wing and, therefore, the lift cannot be increased any further.

The purpose of transferring air from the pressure side to the suction side of an airfoil is, therefore, to maintain throughout a
60 wider range of angles of attack, a smoother flow that will follow the contour of the airfoil. This is usually called "boundary layer control". The supply of air may also be obtained, as illustrated in Figs. 7, 8 and 9, from
65 scoops placed at suitable points, preferably

on the pressure side of the wing. Said scoops can be rigged up when not needed thereby reducing the overall air resistance to motion. When radiators are used, the air past the radiators can be collected into the wing, as
70 illustrated in Fig. 10, for the purpose herein described. The heated air will serve at the same time to avoid ice or sleet formation on the wings. If one or more aircooled engines are used, it can be arranged to collect
75 the heated air past the engine in such a way as to pour it into the wing structure, as illustrated in Fig. 11, for the duofold purpose also of increasing the lift and avoiding ice or sleet formation.
80

Any number of intake openings or passages to pour or force the air into the wing may be used; and also any number of openings may be arranged in the top. Preferably, these should be narrow slots extending span-
85 wards of the wings.

As shown in Fig. 1, a passage 1 is located on the under or pressure side of the airfoil adjacent the forward edge at the point of maximum pressure on the airfoil and admits air to the chamber within the airfoil, which is indicated by the numeral 1a in the drawings, and which is provided with exit openings 2, 3 and 4 to the upper or suction side of the airfoil. By placing the inlet opening
90 1 at the point of greatest pressure, a greater volume of air will be forced into and through the airfoil than would be the case if the inlet opening were placed elsewhere. At steep angles, the difference of pressure between the
95 under face and the upper face of the airfoil establishes a current of air through the outlet openings in the direction indicated by the arrows which tends to blow away the "dead air" or eddy region above the upper face,
100 causing the air to follow closely the profile of the upper face so that the wing positioned at a steep angle imparts a greater downward impulse to the air with the result that a greater lift is obtained.
105

In Fig. 2, a flap 5 is provided along the rear edge of the airfoil which may be moved backwards and swung downwardly to control the pressure on the under side of the wing, as described in my application No. 236,342, above
115 referred to. In all flap and wing combinations, a relatively high pressure is built up in the vertex of the angle between the flap and wing, and this excess pressure will force air through openings 6 in the wing adjacent the flap and through the chamber 1a to the out-
120 let slots 2, 3 and 4 and the flow of air will vary as the angle of the flap is varied. If desired, an inlet opening such as shown in Fig. 1 may be provided in addition to the opening 6 in airfoils such as shown in Figs. 2, 3, 4 and 6.
125 The flap 5 may be formed as shown in Figs. 3, 4 and 6 to close or substantially close the opening 6 when in its uppermost position.

In Fig. 3, the flap 5 is hinged at 7 and when
130

pulled down, opens the inlet passage 6 to the chamber 1a to supply air to the outlet passages 2, 3 and 4. An extra opening 8 between the flap 5 and the body of the airfoil can be provided, if desired. As shown in Fig. 3, a plurality of springs 9 in tension may be connected to the wing and flap to facilitate the operation of the flap. The point of attachment 10 of the spring 9 to the flap is so located that the spring loads produce smaller torque loads about pin 7 when the flap is up, said loads increasing gradually as the flap is brought down. The air loads in torque about pin 7 increase also as the flap goes down but with an opposite sign, with the result that both loads tend to counteract each other, thus releasing the operator from a part or all the effort required to operate the flap.

Fig. 4 shows a hollow airfoil having a top wall in the form of a plate which has a number of small passages 11 tending to direct outgoing air toward the trailing edge. The clearances between the flap and wing forming the passage at 8 may be such as to increase gradually the size of the passage as the flap moves down or, if desired, they may be such as to provide a passage of substantially unvarying size for any position of flap 5. As shown in dotted lines indicated at 12 in Fig. 4, the flap 5 may be adjusted to a negative angle so that it may be used as an aileron for lateral control. The passage 6 is closed upon upward adjustment of the flap or aileron and opened upon downward adjustment which results in a lateral control of greater effectiveness due to the aggregated effect of the ailerons themselves, as in the usual aileron control, plus the effect due to the "boundary layer control," as previously explained. The inner end of the aileron, when the aileron is adjusted to a negative position, protrudes past the lower face of the airfoil and causes a greater drag which reduces the total yawing moment due to both ailerons. In case the boundary layer control provided by the present invention is used for improving aileron control only, the extent in which openings 11 should extend spanwards on the wing should not be more than what may be required for obtaining the desired improved aileron control.

Fig. 5 shows a front opening in the lower face of the airfoil corresponding to the opening 1 in the modification shown in Fig. 1 and this opening is provided with a shutter 13 mounted to pivot about a pin 14 to control the passage of air to the chamber 1a. The exit openings 2, 3 and 4 are also provided with pivoting shutters 15, 16 and 17. All of said shutters are connected by linkages 18, 19 and 20 to an operating lever 21 by which the shutters may be adjusted to the desired position. This arrangement has the advantage of providing smooth wing surfaces for normal flying with the resulting reduction in profile drag.

In the modification shown in Fig. 6, the openings to the upper surface of the airfoil are provided with pivoting shutters 15, 16 and 17, which are connected by linkages 18, 19 and 20 to the adjustable flap 5, so that the movements of the shutters are simultaneous with the movements of the flap. When flap 5 is moved down about its pivot 7, the shutters 15, 16 and 17 are simultaneously moved downwardly to open the outlet passages 2, 3 and 4, the shutters moving gradually to increase the size of the outlet passages as the flap is moved down. The passage 6 is opened at the same time so that the flow of air into the chamber 1a and through the outlet passages is dependent on the angle of the flap. The advantage of this arrangement is to provide a smooth surface when the high lift mechanism is operated and to obtain higher lift values and a lower angle of attack than with the openings and shutters alone.

Fig. 7 shows exit openings 2 and 3 provided with shutters 15 and 16 which are linked by a rod 19 and controlled by lever 21 such as previously described in connection with Fig. 5. Inlet openings to the chamber 1a are provided on the under side of the wing adjacent the forward edge and a scoop 23 is connected by a hinge 24 to the rear edge of the opening to increase the volume of air delivered into the chamber 1a. The opening and closing movements of the scoop occur simultaneously with those of the shutters 15 and 16 by reason of the linkage 25 connecting the scoop to the shutters, these movements being controlled by the lever 21 so that when the shutters are closed, the scoop is also closed and vice versa. The width of the scoop spanwards may be limited to a small portion of the span and also a plurality of scoops can be placed along the span. The sides 26 of the scoop are moved into the wing as the scoop is closed, occupying, in the closed position of the scoop, the position shown by the dotted lines in Fig. 7. This arrangement provides a substantial increase of lift without the addition of a flap and provides a smooth profile when the control device is idle.

Fig. 8 shows a plurality of upper openings 2, 3 and 4 and adjustable louver plates 27, 28 and 29 that serve as shutters for the exit openings. The louver plates are pivoted at the forward edges of the openings and are linked together by rods 18 and 19 so that they can be operated by a lever 21, corresponding to the operating lever shown in Figs. 5 and 7. The air is admitted to the chamber 1a through openings 30 and 31 in the under side of the airfoil. These openings can be shut at will by louver plates 32 and 33 hinged to the body of the airfoil adjacent the rear edges of the openings. The movements of the louver plates 32 and 33 are caused to be simultaneous with each other and with those of shutters 27, 28 and 29 by means of linkages 34 and 35.

This arrangement provides a positive intake of air when required and provides a smooth airfoil contour when the openings are closed. If desired, the operation may be made automatic by connecting the lever 21 to the air foil through a spring 88, which tends to hold the shutters closed. In this case, I would prefer to disconnect the linkage 35 and to have shutters 32 and 33 operated independently by an additional handle 89. This automatic operation, which can be applied to any type of shutter, has obvious advantages.

I prefer to surround the openings with fairings rounding the edges so as to obtain a smoother flow in and out of the airfoil. These fairings are shown by 36, 37, 38 and 39 in Fig. 8. Fairings of other suitable shapes can be used.

Fig. 9 represents another form of intake opening located at the forward edge of the airfoil in which cover plates 41 and 42 are pivoted at their rear edges and connected for simultaneous movements in opposite directions by linkage 43, a lever 21 serving to adjust the position of the cover plates. Plate 41, when open, serves to deflect the air into the chamber 1a of the wing. This double cover plate arrangement can be placed along the whole span of the airfoil as well as along a part only of it, or, if preferred, a plurality of such assemblies can be placed in a single wing. The plates 41 and 42 are preferably so designed that when in engagement with each other, they close the wing practically airtight so as not to allow air leakages, and to let escape air only when and where desired. This form of control may be used with or without the flap or aileron.

Fig. 10 shows a boundary layer control system employing heated air in which the engine is the source of heat. The engine, in this case, may be of the water cooled or "steam cooled" type suitably connected to a radiator 53. The radiator 53 is exposed in front and the air heated in passing through the radiator can be permitted either to pass straight backwards through an opening controlled by a louver 54 or when the louver 54 is closed, to pass downwards into the chamber 1a of a wing 46 to supply the necessary air to openings of any of the types described.

Louver 54 is hinged at 55 and is linked to pivoted louver plates 56 and 57 through rods 58 and 59. A handle 21 controls the motions of the three louvers described so that when louver 54 is open, louver plates 56 and 57 close the passage of air into the wing and vice versa. Dotted lines show the motion described by the three louvers. This arrangement, in addition to providing the boundary layer control serves to prevent ice or sleet formation on the wing when flying in cold weather.

Fig. 11 shows a modification having two exit openings 2 and 3 with shutters 27 and 28

and intake shutter 32 linked together and operated by handle 21, as previously described in connection with Fig. 8. Passages 61 and 62 are provided within the airfoil lengthwise thereof through which hot air obtained from the engine or any other source is circulated. Several holes of any shape may be provided along the length of these passages, as shown at 63 and 64 to permit the hot air to mingle with the incoming air. The hot air circulated through 61 and 62 can be replaced by exhaust gases from the engine or engines or by a mixture of air and exhaust gases.

The air allowed through opening 30 to chamber 1a is thus heated and ice or sleet formation is avoided.

Fig. 12 shows a modification in which a hollow airfoil section 65 is provided with openings 66, 67 and 68 in the upper wall of the airfoil communicating with the chamber 1a. The pressure distribution on the suction side of an airfoil at high angles is approximately as shown by arrows 69 and envelope curve 70. Greater depression is therefore found in the neighborhood of the opening 66 than around the openings 67 and 68. The opening 66 is formed to favor an outgoing flow while the openings 67 and 68 are formed to favor an ingoing flow. Thus, a circulating flow will be established tending to increase the lift on the one hand by reason of the fact mentioned above, that blowing air out as well as sucking it in produces a smoother flow above the wing with a resulting increase in the lift, and on the other hand, by the fact that the "relative circulation" is increased and that the lift is proportional to said relative circulation. More or fewer openings than shown may be provided and the relative location of the openings may be altered, as may be desirable, to obtain the best efficiency. Also, shutters for the openings such as previously described may be used.

Fig. 13 shows a modification in which movable vanes 71 and 72 are connected to the flap 5 in such a manner that when the flap 5 is lowered, as shown in the figure, the vanes 71 and 72 are opened to permit air exit through 2, 3 and 4. The vanes 71 and 72 are mounted on pivots 73 and 74 respectively, and through a lever 75 and a rod 76, the motions of the flap are transmitted to a lever 77 which swings about a pivot 78 on the body of the airfoil. The lever 77 controls the motion of the vane 72 through a link 79, also it acts on a bell crank 80 pivoted at 82 through a rod 81, which controls the motion of the vane 71. When the flap 5 is brought down, the circulation of air through the chamber 1a is established as described above in connection with Figs. 3 and 6. This provides a simple mechanical arrangement of

shutter control of substantial construction and positive operation.

Fig. 14 shows an airfoil section similar to that shown in Fig. 1, provided with a flap 5 of the sliding type, as previously mentioned in connection with Fig. 2. This combines the advantages of the "boundary layer control" with those of flap control with the resulting increase of lift.

The flap arrangements shown in Figs. 3, 4, 6 and 13, or other types of flap may be used for lateral control and, when so used, the flaps are preferably so connected that the movements of the flap or flaps on the starboard side are reverse to that of the flap or flaps on the port side. Any of the usual types of control may be used, a suitable control being illustrated in Fig. 15 of the drawings in which the flaps 5 are connected to torsion tubes 90 and 91, which carry bevel gears 92 and 93 at their inner ends which mesh with a bevel gear 94 to which an operating lever 95 it attached, so that movement of the lever 95 causes one flap to swing upwardly and the other downwardly.

In Fig. 3 of the drawings, there is illustrated a further means of lateral control which may be used independently of the flap or aileron control, or in addition to the flap or aileron control to increase the responsiveness. This lateral control device comprises a butterfly shutter 85 pivoted at 86 and operated by means of a suitable handle 87 to regulate the flow of air through the body of the airfoil. As the shutter 85 of a wing is moved toward closed position, the lift on the wing is reduced so that lateral control may be obtained without adjusting the angle of the aileron or flap.

It is to be understood that the butterfly shutters for lateral control may be employed in connection with an intake such as shown in Fig. 1 and other modifications herein shown, the position of the shutters in each case determining the amount of lift on the particular wing in which the shutter is mounted.

It will thus be seen that I have provided advantageous and simple means to control the flow of air surrounding airfoils whereby greater lift can be obtained with a given wing area without the assistance of an accessory pumping plant to provide compressed air or to draw air from the suction side of airfoils.

Furthermore, it is to be understood that the various modifications shown and described, and the particular procedure set forth, are presented for purposes of explanation and illustration and that various modifications of said apparatus and procedure can be made without departing from my invention as defined in the appended claims.

What I claim is:

1. An airfoil having a flap adjacent its rear

edge and adapted to be positioned at an angle to the airfoil, and means for transferring air from a point on the airfoil surface adjacent the vertex of the angle between said airfoil and flap to the forward part of the suction side of the airfoil.

2. An airfoil having a flap on its under side adjacent its rear end and a passage extending forwardly through the airfoil and connecting the high pressure side near the vertex of the angle between the airfoil and flap to low pressure regions on the upper side of the airfoil.

3. A hollow airfoil having a movable flap along its rear edge, and means controlled by movements of the flap for establishing communication through the interior of the airfoil between the high pressure region of the pressure side of said airfoil adjacent the flap to the low pressure regions on the suction side of the airfoil forwardly of said high pressure region.

4. An airfoil having an angularly movable flap extending along the span adjacent the rear edge thereof, a passage extending forwardly through the airfoil connecting the high pressure region on the pressure side of said airfoil adjacent the flap to the low pressure regions on the suction side of the airfoil, means connected to the flap for simultaneous movement therewith for controlling said passage.

5. An aeroplane having hollow wings provided with independently movable flaps extending lengthwise thereof along their rear edges, and means controlled by movements of the flaps to establish communication through the interior of the wings between the high pressure regions on the pressure sides of said wings adjacent the flaps and the low pressure regions on the suction sides of the wings.

6. A hollow airfoil, means for collecting air within the airfoil, and parallel longitudinally extending shutters arranged one in advance of another and forming a part of the airfoil on the suction side thereof.

7. A hollow airfoil having a flap connected thereto and adapted to project downwardly and rearwardly at an angle to the airfoil, an air passage connecting the interior of the airfoil to the pressure side of the airfoil forwardly of the flap adjacent the vertex of the angle between the airfoil and flap and an outlet passage connecting the interior of the air foil to the suction side thereof forwardly of the first mentioned passage.

8. A hollow airfoil having a flap adapted to project downwardly and rearwardly at an angle thereto, a passage connecting the interior of the air foil to the pressure side of the airfoil forwardly of the flap adjacent the vertex of the angle between the airfoil and flap, an outlet passage connecting the interior of the airfoil to the suction side thereof for-

wardly of the first mentioned passage, and adjustable shutters controlling the flow of air through the airfoil.

5 9. A hollow airfoil having an adjustable flap extending along the rear edge thereof and adapted to be positioned at a downward inclination with respect to the airfoil, an inlet passage leading from the pressure side of the airfoil to the interior thereof adjacent the flap and forwardly thereof, outlet pas-
10 sages from the interior of the airfoil to the suction side thereof forwardly of the first mentioned passage, and shutters for controlling the flow of air through said passages.

15 10. A hollow airfoil having a flap extending along its rear edge and adjustable to a downwardly inclined position with respect to the air foil and means including air passages in the air foil for transferring air forwardly
20 through the interior of the airfoil from the part of the airfoil surface adjacent the vertex of the angle between said airfoil and flap to the suction side of the airfoil.

11. An aeroplane having hollow port and
25 starboard wings, said wings having perforated walls on the suction sides thereof, a flap at the rear edge of each wing, and inlet openings to the pressure sides of the wings along the rear edges thereof adjacent said flaps.

30 12. An aeroplane having hollow port and starboard wings provided with perforated walls on the suction sides thereof, each wing having an adjustable flap extending along the rear edge thereof, means for adjusting the
35 flaps with the movement of one flap reverse to that of the other, and inlet openings to the pressure sides of the wings along the rear edges thereof adjacent the flaps.

In testimony whereof I affix my signature.

40 HERACLIO ALFARO.

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