

June 2, 1925.

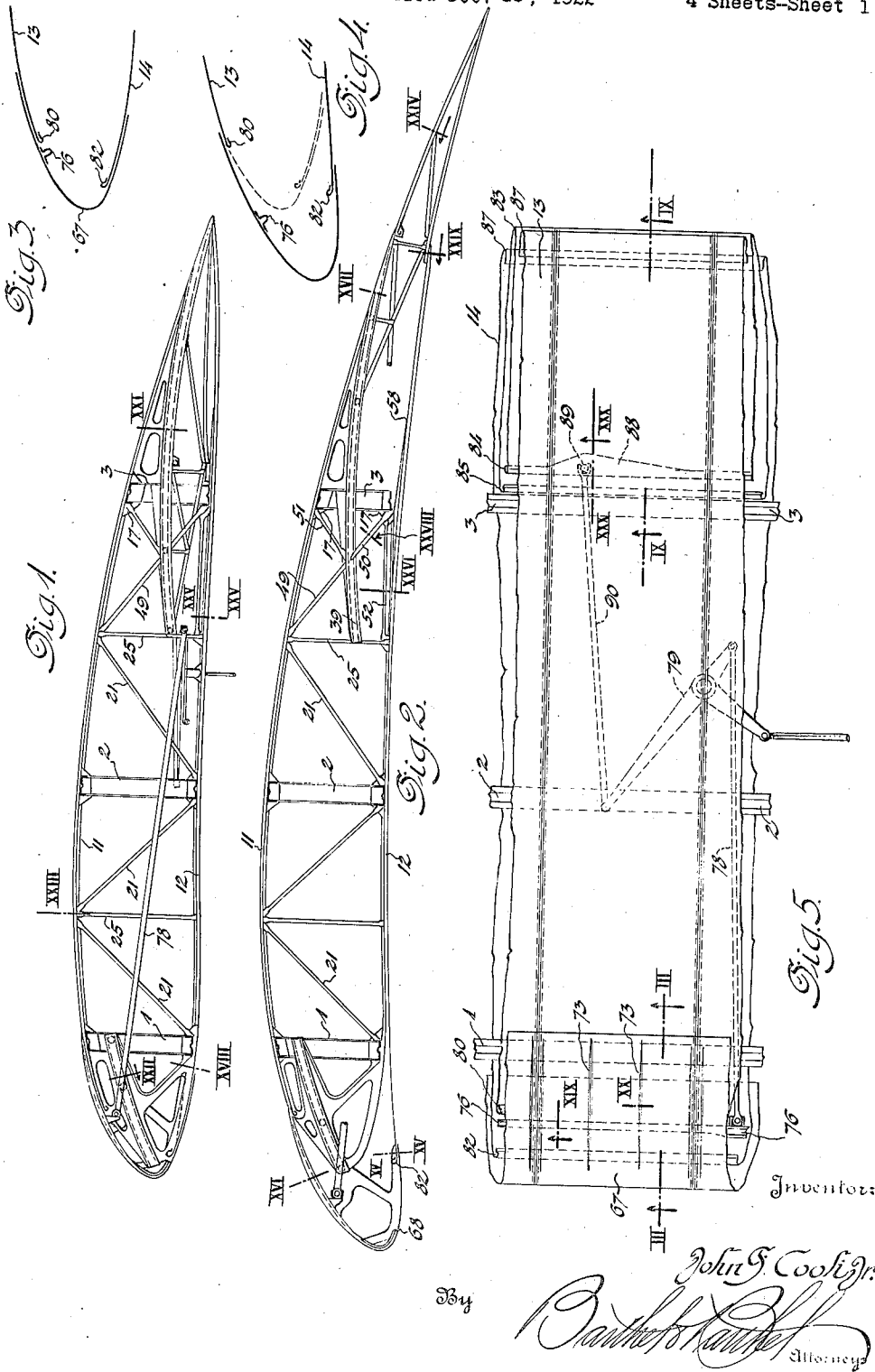
J. F. COOK, JR

1,540,105

AIRPLANE

Filed Dec. 18, 1922

4 Sheets-Sheet 1



June 2, 1925.

J. F. COOK, JR

1,540,105

AIRPLANE

Filed Dec. 18, 1922

4 Sheets-Sheet 3

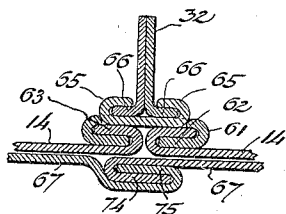
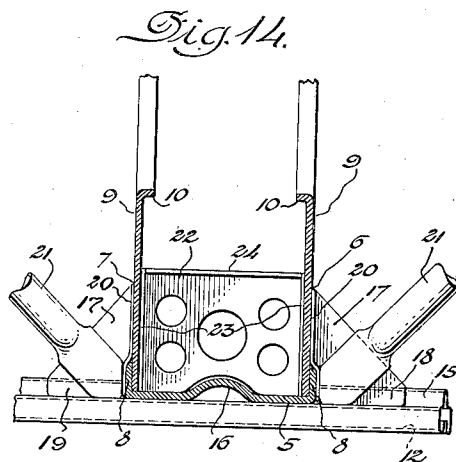
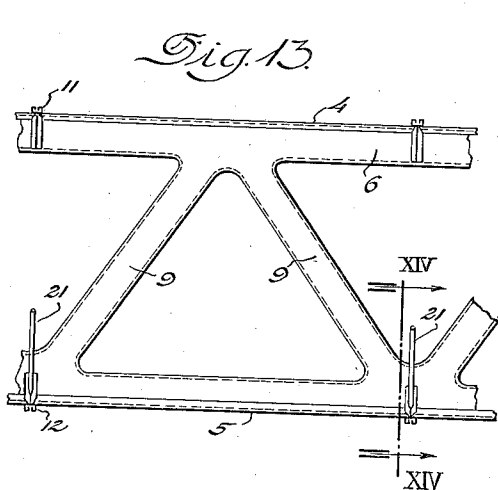


Fig. 15.

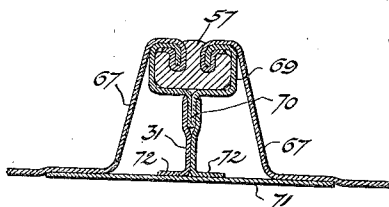


Fig. 16.

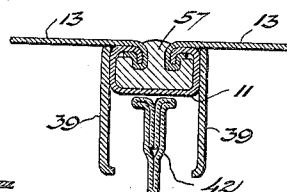


Fig. 17.

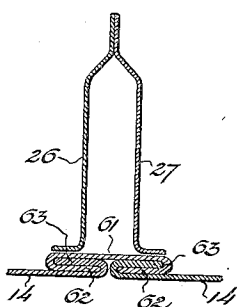


Fig. 18.

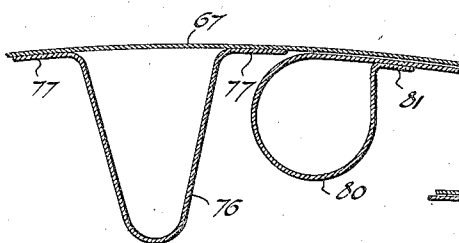


Fig. 19.

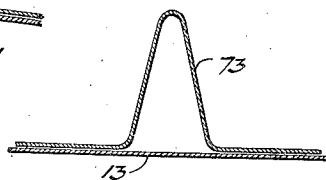


Fig. 20.

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By

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AIRPLANE

Filed Dec. 18, 1922

4 Sheets-Sheet 4

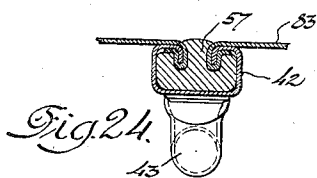
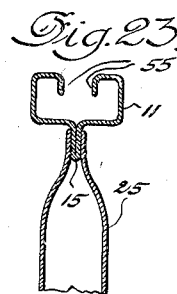
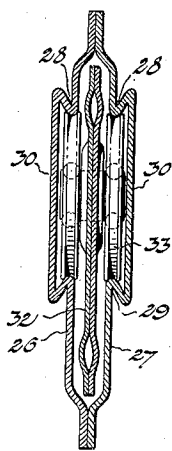
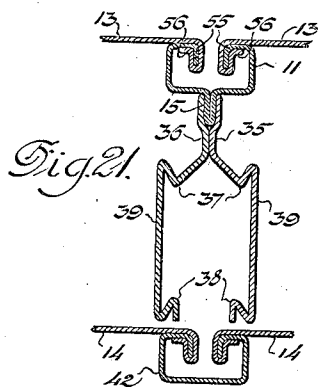


Fig. 22.

Fig. 25.

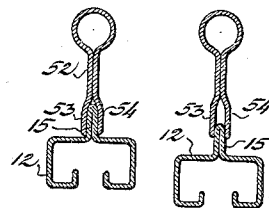


Fig. 26.

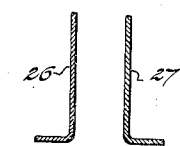


Fig. 27.

Fig. 28.

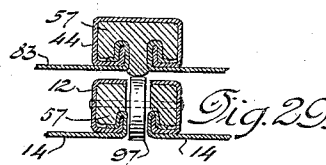
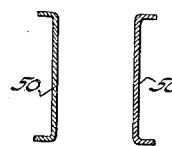


Fig. 29.

Fig. 31.

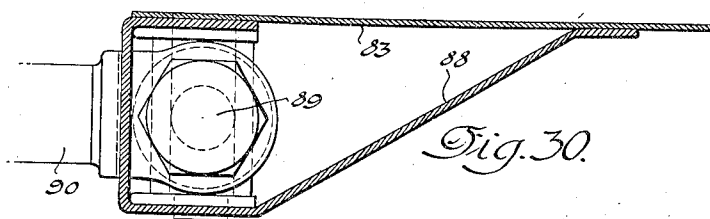
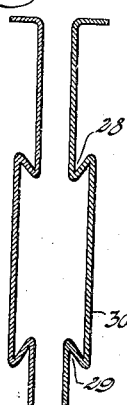


Fig. 30.

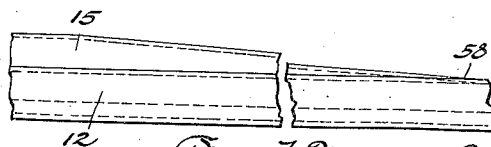


Fig. 32.

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UNITED STATES PATENT OFFICE.

JOHN F. COOK, JR., OF DETROIT, MICHIGAN.

AIRPLANE.

Application filed December 18, 1922. Serial No. 607,539.

To all whom it may concern:

Be it known that I, JOHN F. COOK, JR., a citizen of the United States of America, residing at Detroit, in the county of Wayne and State of Michigan, have invented certain new and useful Improvements in Airplanes, of which the following is a specification, reference being had therein to the accompanying drawings.

10 This invention relates to an internally trussed aerofoil of metallic construction, and has for its object the provision of means by which the area, the camber, and the angle of incidence may be varied simultaneously without varying the relation of the main portion of the aerofoil with respect to the line of flight.

15 A further object of the invention is the provision of an aerofoil having a cross section of low camber for high efficiency at small angles and high speed which may be varied to a cross section of relatively deep camber and a high lift efficiency at low speeds while maintaining a minimum drift co-efficient by utilizing the flexibility of the lower sheet metal covering to obtain a gradual curvature of the lower surface at all points during the various stages of adjustment.

20 Another object is to provide an aerofoil having movable nose and trailing portions to produce variable area and variable camber, in which both the top and bottom surfaces throughout the entire range of adjustment have a minimum discontinuity of curvature.

25 A still further object of the invention is to provide a construction of aerofoil in which the use of rivets and wires is avoided and in which the sheet metal plates forming the covering of the aerofoil may be readily removed and replaced when repairs are necessary.

30 Other and further objects of the invention will appear during the accompanying description in conjunction with the drawings forming a portion of the specification, in which—

35 Figure 1 is a vertical cross section, on the line I—I of Fig. 8, of a preferred form of aerofoil at the position of adjustment having the greatest efficiency for high speed;

Fig. 2 is a corresponding section of the same aerofoil having its movable nose and trailing portions projected to increase the area and to produce a cross section of high efficiency for low speed;

Fig. 3 is a sectional view on the line III—III of Fig. 5 of a fragment of the forward edge or nose of the aerofoil between the ribs showing the relation of the sheet metal surface plates in the closed position corresponding to Fig. 1;

Fig. 4 is a similar fragmentary section showing the relation of the sheet metal surface plates of the nose portion in the extended position corresponding to Fig. 2;

Fig. 5 is a fragmentary plan view on a larger scale than that of Fig. 8;

Fig. 6 is an elevation of a rib secured to the movable nose portion shown as separated from a co-operating terminal member forming a part of a rib of the central fixed section of the aerofoil;

Fig. 7 is a side elevation of a terminal member secured to each rib of the central fixed section at its rear end, together with a rib of the movable trailing portion, the two members being shown in their operative relation when the trailing portion is partly extended;

Fig. 8 is a plan view of an aerofoil showing a central panel having the movable nose and trailing portions completely closed, and a left wing panel with the movable portions partially projected, the right wing panel being broken away;

Fig. 9 is a diagrammatic fragmentary section through the sheet metal covering members between the ribs in the closed position of the trailing portion;

Fig. 10 is a similar diagrammatic fragmentary section showing the movable rear trailing portion projected;

Fig. 11 is a fragmentary elevation showing the manner of attachment of truss members to a top chord member of a rib;

Fig. 12 is a perspective view of a fragment of the interior of the lower front portion of the aerofoil adjacent to the leading spar;

Fig. 13 is a fragmentary elevation of one of the beams or spars;

Fig. 14 is a vertical transverse section of a

portion of a beam on the line XIV—XIV of Fig. 13, looking in the direction indicated by the arrow;

Fig. 15 is a vertical section taken on the line XV—XV of Fig. 2;

Fig. 16 is a section taken on the line XVI of Fig. 2;

Fig. 17 is a section taken on the line XVII of Fig. 2;

Fig. 18 is a section taken on the line XVIII of Fig. 1;

Fig. 19 is a section taken on the line XIX of Fig. 5, looking in the direction indicated by the arrow;

Fig. 20 is a section on the line XX of Fig. 5;

Fig. 21 is a section on the line XXI of Fig. 1;

Fig. 22 is a section on the line XXII of Fig. 1, looking in the direction indicated by the arrow;

Fig. 23 is a section on the line XXIII—XXIII of Figs. 1 and 11;

Fig. 24 is a section on the line XXIV of Figs. 2 and 7, looking in the direction indicated by the arrows;

Fig. 25 is a section on the line XXV—XXV of Fig. 1;

Fig. 26 is a section on the line XXVI of Fig. 2;

Fig. 27 is a section on the line XXVII—XXVII of Fig. 6;

Fig. 28 is a section on the line XXVIII of Fig. 2;

Fig. 29 is a section on the line XXIX of Fig. 2, looking in the direction indicated by the arrow;

Fig. 30 is a section on the line XXX—XXX of Fig. 5;

Fig. 31 is a section on the line XXXI—XXXI of Fig. 6; and

Fig. 32 is a fragmentary elevation of a portion of the lower chord member.

It is well known that the wing curvature is a determining factor in the efficiency of an aerofoil. An aerofoil of low camber having a relatively low lift has been found to have high efficiency at small angles of incidence and at high speeds, and the area at such speeds may be made very small. However it is essential that the speed at the time of landing shall not be so great as to endanger the safety of the pilot or of the airplane. The most efficient wing section for low speeds is not the most efficient section for high speeds.

Generally speaking, a high speed type of machine requires a totally different wing section and incidence to a low or moderate speed type. The actual wing sections of airplanes have hitherto been a kind of compromise between fast and slow speed sections in order to insure safe landing and "getting off."

Where the greatest maximum speed is the

first and foremost consideration, an approximation to a stream line wing section at a small angle of incidence, varying from 0° to 2° is necessary. Further, it is essential that the position of the center of pressure for the fastest flying angle shall be quite stable, and with a margin of safety in case of unforeseen circumstances causing a further decrease of angle of incidence. For slow flying, a wing section characterized by good upper and lower surface cambers, and comparatively large angles of incidence, is necessary. Further, it is essential that the angle of incidence for slow flying shall not be too near to the critical angle at which the lift co-efficient decreases and the drift increases, and that at the maximum angle of incidence the center of pressure shall have a stable position.

For a good speed range, a wing section should have the following qualities:

The center of pressure for the range of flying angles used should have a stable position and the minimum range of movement along the chord. In a good wing section, the center of pressure at all angles of incidence used in flying, ascending or alighting should lie between 30% and 45% of the chord to the rear of the leading edge.

The lift co-efficient should increase continuously from a negative or zero angle to about 15° and it should then remain constant and decrease at a slow rate without having a sharp critical angle. The maximum lift co-efficient should not be lower than 0.65 and the maximum drift co-efficient ought not to exceed 0.10.

At the small angles of incidence used with the highest speeds, the drift co-efficient should be a minimum, and for the minimum expenditure of horse power at the maximum speed, the lift co-efficient at the minimum value of the drift co-efficient should be sufficient for the wing area chosen to support the load at that speed.

Two methods of improving the performance of an airplane have been suggested, but have hitherto not been put into common use because of the mechanical difficulties involved. One method is to increase the wing area just before landing. The other is to increase the lift co-efficient when landing.

The aerofoil illustrated herewith has a structure permitting the simultaneous projection of front and rear movable portions to increase the area, each of the movable portions following a curved path, and each, as the result of its movement, causing the metal plates constituting the lower surface of the aerofoil to bend in such manner that the section of the aerofoil is changed from one of low camber when these portions are closed to one of deep camber when the movable portions are fully opened. Furthermore, the rate of projection of the rear movable

trailing portion is greater than that of the front or nose portion, and the curved path of movement is such that when the movable portions are fully projected, not only are the area and camber altered, but the angle of incidence is also increased, whereby the fuselage may be maintained in a position in which it offers a minimum resistance and wherein the propeller has its axis maintained substantially parallel to the line of flight, this being its position of maximum efficiency.

The position of the maximum ordinate of an aerofoil is an important factor in determining the location of the center of pressure. The relative movement of the front and rear movable portions, for any given relation that may exist between the sections of the aerofoil in its fully closed and in its fully opened positions, will be determined in such manner that during the change in position of the movable parts the maximum ordinate will move slightly to the rear with respect to the fixed portion of the aerofoil. Movement of the maximum ordinate to the rear will normally cause rearward movement of the center of pressure. Conversely, increase in the angle of incidence will normally cause forward movement of the center of pressure. The variation in the wing section during opening movement of the nose and trailing portions produces rearward movement of the maximum ordinate which tends to move the center of pressure to the rear. The higher rate of movement of the trailing portion causes an increase in the angle of incidence of the aerofoil which tends to move the center of pressure forward. These two factors counterbalance each other.

Either forward movement of the front movable portion or rearward movement of the trailing portion of the wing would cause a movement of the center of pressure, but by causing the proper relative movement of both to occur simultaneously, the effect of one may be made to balance that of the other and the center of pressure will thus remain at substantially the same place.

Slight movement of the maximum ordinate to the rear increases the lift co-efficient at higher angles of incidence and at the same time counteracts the forward movement of the center of pressure due to increase in the angle of incidence.

The lift may be increased by an increase in area, by an increase in the angle of incidence, and by an alteration of section.

As the nose and trailing portions are projected in the aerofoil of the present invention, the lift is increased by the simultaneous action of each of these three factors. Lateral control of an airplane may be obtained by varying the relative lift upon the panels on opposite sides of the fuselage, this

variation being produced in the present aerofoil by varying the relative amount of projection of the movable portions.

In my co-pending application, Serial No. 607,538, filed Dec. 18, 1922, I have described a control mechanism for accomplishing this variation in area of the aerofoil panels.

The aerofoil illustrated in the accompanying drawings is constructed entirely of metal, the beams and ribs being preferably made of alloy steel members secured together by electric spot welding, while the sheet metal plates covering the surfaces will preferably be of aluminum or of light metallic alloys.

In Fig. 1, the main beams or spars are shown with the spar 1 located near the front edge of the fixed portion of the aerofoil, the spar 2 opposite the center of pressure and the spar 3 near the rear of the fixed portion. These spars consist of an upper plate 4, a lower plate 5 and side plates 6 and 7, the plates 4 and 5 being preferably formed with flanges 8 as shown in Fig. 13, secured by spot welding to the side plates 6 and 7. The side plates 6 and 7 will preferably be stamped out to form diagonal brace members 9, flanges 10 being formed around the stamped out portions to provide rigidity. Sheet steel ribs 11 and 12 are secured to the upper and lower edges respectively of the spars 1, 2 and 3, these ribs being in the form of channels adapted to receive the edges of the sheet metal plates 13 and 14 forming the covering of the upper and lower surfaces of the aerofoil.

The ribs 11 and 12 are secured to the spars as indicated most clearly in Fig. 14. Each rib is provided with a central flange 15 formed by bending the sheet metal upon itself to project outwardly at right angles to the body of the rib. Opposite the plate 5 this flange 15 of the rib is cut away to permit the body of the rib to lie closely in contact with the face of the plate 5 on opposite sides of the strengthening corrugation 16. Brace members 17 shown in Fig. 14 are preferably formed of thin sheet steel folded upon itself to provide parallel members 18, 19, separated along one edge to embrace opposite sides of the flange 15 and flanged along the other edge at 20 to abut against the plates 6 and 7 and the flanges 8, the folded edge forming the hypotenuse of each triangular brace member. The flanges 20 will be secured by spot welding to the plates 6 and 7 and to the flanges 8, and the edge portions 18 and 19 will be spot welded to the flange 15. Tubular drawn steel braces 21 have their ends flattened and separated to engage upon opposite faces of the brace member 17, the ends of the members 21 being shaped to fit closely within the corners formed by the flanges 20 and the body of the rib 12. The overlapping flattened

ends of the braces 21 will also be spot welded to the brace member 17.

Between the plates 6 and 7 at the point at which the braces 17 engage the outer faces of the plates is located an interior brace member 22 having flanges 23 welded to the inner faces of the plates 6 and 7 and having a flange 24 formed along its upper edge to provide additional rigidity. This plate may be perforated for the sake of lightness.

The braces 21 extend diagonally from the lower sides of the spars 1, 2 and 3 upward to engage the flange 15 upon the lower surface of the upper rib 11 between the spars. As shown in Fig. 11, between the adjacent ends of the braces 21 where they lie in contact with the flange 15 is the flattened end of the tubular brace 25 which extends between the ribs 11 and 12, at substantially right angles to each. The flattened ends of the braces 21 and 25 shown in Fig. 11 are secured by spot welding to the flange 15.

At the forward edge of the aerofoil, sheet metal members 26 and 27 are secured to the leading spar 1 as indicated in Fig. 6. These sheet metal members are symmetrical in construction and arranged parallel with each other to form a channel indicated in section in Figs. 22 and 31. The sheet metal is bent as indicated at 28, 29 to form upper and lower curved tracks connected by side walls 30. Above and below the tracks, the sheet metal members 26 and 27 meet as shown in Figs. 6 and 22 toward the rear end of the structure, but toward the front end, the plates are separated above as indicated in Fig. 31 and below as indicated in Fig. 27 to permit the passage of the rib member 31 secured to the movable nose portion of the aerofoil. This rib member is composed of sheet metal plates having their front edges of the contour desired for the forward edge of the movable nose portion of the aerofoil and the central portion is formed as a rearwardly projecting bearing bracket 32 upon which are journaled rollers 33 having grooved peripheries adapted to engage the tracks formed by the folds of sheet metal at 28 and 29.

In Figs. 7 and 21, is illustrated a rear sheet metal track member 34 secured to the trailing spar 3 and to the upper rib 11. This member 34 consists of symmetrically shaped parts 35, 36 bent at 37 and 38 to form upper and lower tracks, connected by side walls 39, with which engage grooved rollers 40 and 41 secured to a rib 42 constituting part of the trailing portion of the aerofoil. At its forward end, the member 34 has the upper edges of its parts 35 and 36 spot welded to the flange 15 of the rib 11, but the channel lying between the upper and lower tracks and the walls 39 is formed on an arc of a circle intersecting the

curve of the rib 11. The rear portions of both the member 34 and the rib 11 are therefore modified to the configuration shown in Fig. 17 in which it will be noted that the member 11 no longer has the flange 15, and the member 34 has the portions above and below the side walls 39 cut away so that the upper inner faces of the side walls 39 lie on opposite sides of the rib 11 and are spot welded thereto. The rear portion of the rib 42 which extends along the upper surface of the trailing portion of the aerofoil is shown in cross section in Fig. 24 at a point immediately at the rear of the rear end of a brace member 43 consisting of a steel tube flattened at both ends and secured by spot welding to the underside of the rib 42 and to the upper side of the rib 44 which lies along the lower side of the trailing portion of the aerofoil. A brace member 45 extends from a point near the front end of the brace 43 and the rib 44 to the forward end of the rib 42 at the point where the roller 40 is journaled. A cross brace 46 extends between the rib 42 and the brace member 45, the upper end of the brace 46 connecting with the rib 42 at the point where the roller 41 is journaled. Another brace member 47 extends between the rib 42 and the rib 44 substantially at right angles to the rib 42, its lower end being secured by spot welding to the brace 45. A brace 48 lies between the upper end of the brace 47 and the lower end of the brace 46, the upper end being secured to the rib 42 and the lower end to the brace 45. As shown in Fig. 7, the rollers 40 and 41 lie between the tracks 37 and 38. The portion of the rib 42 lying to the rear of the upper end of the brace 47 is curved on an arc of a circle concentric with the curvature of the tracks 37, 38, but having a slightly smaller radius and the portion of the rib 42 between the upper ends of the braces 46 and 47 lies at somewhat of an angle to the portion of the rib 42 between the rollers 40 and 41 so that as the rollers 40 and 41 run along the tracks 37 and 38 in the arc of a circle, the upper surface of the rib 42 will move along a concentric circle and therefore will not move away from the extreme rear end of the lower surface of the rib 11. The forward end of the rib 42 lying between the rollers 40 and 41 is compressed into the configuration shown in section in Fig. 17.

The extreme forward end of the side walls 39 are spot welded on opposite sides of the brace member 25 which extends between the ribs 11 and 12 substantially midway between the spars 2 and 3. A brace 49 similar to the brace 21, but shorter, extends between the rib 11 and the upper edge of the plates 35 and 36, the upper end of the brace being flattened and overlapping the flange 15 after the manner indicated in Fig. 130

11, while the lower end is also flattened to overlap the upper edges of the plates 35 and 36. A brace member 50 consisting of two channel shaped plates shown in section in Fig. 28 extends between the lower edge of the side walls 39 and the brace 17 at the lower edge of the forward face of the trailing spar 3, the upper end of the plates 50 being secured on the outer faces of the walls 39 at a point opposite the lower end of the brace 49. The brace 51 extends upward from the upper edge of the plates 35, 36 adjacent to the lower end of the brace 49 to the brace 17 which in turn is secured to the rib 11 and the upper portion of the forward face of the trailing spar 3. Between the brace plate 17 at the lower edge of the spar 3 and the lower end of the brace member 25 to which the forward end of the walls 39 are secured, extends a brace member 52 shown in cross section in Figs. 25 and 26. This brace member 52 is made of a sheet of steel folded centrally in the shape of a tube along its upper edge, the free edges 53, 54, being separated and the portion between the free separated edges and the tubular portion being secured together by welding. At its forward end, the free edges 53 and 54 embrace the flange 15 lying along the upper surface of the rib 12 and may be secured thereto by spot welding adjacent to the lower end of the brace 25. To the rear of this forward end, however, the flange 15 is not secured to the free edge portions 53 and 54, but the rib may be bent downward so that the flange 15 will be partly withdrawn from the channel between the free edges 53 and 54 as indicated in Fig. 26.

The method of securing the sheet metal plates 13 to the ribs 11 is indicated in Figs. 17 and 21.

As most clearly seen in Fig. 21, the free edges of the sheet steel constituting the channel portion of the rib 11 extend inward toward each other in the same plane and are then bent at substantially right angles to that plane inward toward the center of the channel to form flanges 55. The sheet metal plates forming the covering of the aerofoil have their edges bent angularly into a hooked shape adapted to engage with the flanges 55 as the edge of the plate is slid longitudinally of the channel from one end of the rib 11. After both plates have been placed within the channel, a forming tool will be drawn longitudinally of the channel to press the free edges of the sheets 13 into the inner corner formed by the flanges 55 with the outer faces of the rib 11 as indicated at 56. The tool is withdrawn and a locking strip 57 preferably of aluminum or of a light alloy will be drawn into the interior of the channel to hold the free edges of the sheets 13 securely locked around the flanges 55 as shown in Fig. 17. It will be

observed that the rib 11 has the flange 15 in certain locations as shown in Figs. 11, 21 and 23, while in other locations the flange 15 is omitted as indicated in Fig. 17, but this does not affect the manner of connecting the plates 13 to the ribs and the locking strip 57 is of the same configuration in every case. The locking strip 57 will preferably be drawn through a die so that its cross section will be uniform throughout its length, thus enabling it to be readily drawn into the channel after the tool has pressed the edges of the sheets into position.

The strip 57 engages the surface of each sheet 13 within the corners formed at 56 thus preventing spreading of the channel. The outer arms of the T-shaped strip 57 lie on opposite sides of the two inwardly extending flanges 55 with the infolded edges of the plates 13 surrounding the flanges and held firmly and uniformly at all points throughout their length.

This gives much greater rigidity and is a much stronger construction than is secured by the use of rivets at a series of separated points along an edge of a plate.

For the sake of clearness, the locking strip 57 has been omitted from the illustration in Figs. 21, 23, 25 and 26.

The ribs 12 of the under surface of the fixed section of the aerofoil are provided with a flange 15 from their forward ends adjacent to the leading spar 1 rearward to a point indicated at 58 in Figs. 2 and 32. Flange 15, as has been stated, is secured to the brace 52 by welding adjacent to the lower end of the brace 25. From this point to the point 58, the flange gradually tapers until it merges with the flat upper surface of the rib, the rib from that point to the rear having a cross section similar to that shown in Fig. 17. At the forward end of the ribs 12 upon the lower surface of the fixed portion of the aerofoil, the channel member is compressed to form a flat vertical web indicated at 59 in Fig. 12, this flattened portion terminating at the leading spar 1. A brace member 60 similar in configuration to the brace member 17 has its forward flanges welded to the side plate 6 of the spar 1, its lower edges embracing opposite sides of the web 59 and being welded thereto. The brace member 21 has its lower end flattened to form parallel lugs engaging on opposite sides of the brace member 60 which are welded thereto.

The rear ends of the sheet metal members 26 and 27 which are L-shaped in cross section, being a continuation of the parts indicated in section in Fig. 18 but having the vertical flanges of less height as shown in Fig. 6, extend beneath the leading spar 1 upon opposite sides of the lower edges of the brace member 60 to which they are spot welded. The sheet metal plates 14 constituting the

covering of the lower surface of the fixed section of the aerofoil are slid from the rear with their hooked edges in the channel of the rib 12 to a point a little to the rear of the leading spar 1. From this point forward, the sheet metal covering 14 must be free to bend downward from the position indicated in Fig. 3 (or in dotted lines in Fig. 4) to the position shown in full lines in Fig. 4. To secure the edges of the sheet metal plates together, while permitting this downward bending, a channel member 61 is provided of the configuration indicated in Figs. 12 and 15. It will be seen that this member consists of a flat strip of metal having its free edges bent inward to form flanges 62 within which engage the flanged ends 63 of the sheets 14. The flanges 62 are slit at a short distance from the rear end and bent upward as indicated at 64 in Fig. 12, these upwardly extending flanged portions being spot welded upon opposite sides of the channel member 12. To the rear of the flange members 64 the free edges of the sheets 14 extend upward into the channel within the rib 12 where they are held by the strip 57. The slits in the flanges 62 at the point opposite the rear end of the flanges 64 enable the flanges 63 to extend beneath the member 61 into engagement with the flanges 62. At the forward end of the channel member 61, the flanges 62 are slit to permit the formation of lugs 65 (Fig. 15) which are curved upwardly in the reverse direction from the flanges 62 to embrace flanges 66 upon the lower edges of the sheet metal members 32 constituting the rib of the nose portion of the aerofoil. The lugs 65 slide freely upon the flanges 66 so that as the sheet metal members 32 move forward from the position shown in Fig. 1 to that shown in Fig. 2, the channel member 61 is bent downward and as the nose portion of the aerofoil is retracted from the position shown in Fig. 2 to that shown in Fig. 1, the flanges 66 engaging the lugs 65 cause the channel member 61 to move upwardly into a position in which it lies with its upper surface substantially in contact with the lower surface of the sheet metal members 26 and 27 as shown in Fig. 18.

The sheet metal covering 67 of the movable nose portion of the aerofoil is secured from the rear of the upper surface of the ribs 31 to a point indicated at 68 in Figs. 2 and 6 on the lower edge of the ribs 31, a little to the rear of the forward end of the ribs by means of channeled members 69, having a flange 70 to which is welded the upper edges of the ribs 31 as indicated in Fig. 16. The strengthening plate 71 is secured to the inner face of the sheet metal covering 67 and to the flanges 72 formed upon the ribs 31. At each of the ribs, the metal covering is bent upward above the

main surface to a height slightly greater than the combined height of the rib 31 and channel 69, the plate 71 secured to the bottom flanges lying substantially in line with the main surface of the sheet 67. The upwardly bent portions of the sheet metal 67 being joined at their upper edges to the channel member 69 by a strip 57, and the channel being secured to the sheets 71 by means of the ribs 31, and the plates 71 being in turn secured to the sheet 67, all as indicated in Fig. 16, there are produced a series of strengthening ribs upon the upper surface of the movable nose portion at the location in which the greatest pressure is sustained, and these ribs are in line with the ribs 11 upon the fixed portion of the aerofoil. Additional ribs 73 are formed in the sheet metal 67 between the ribs 31, the cross section of these ribs being indicated in Fig. 20. From the point 68 to the rear of the movable nose portion, the metallic sheets 67 are secured together by the interlocking flange connection indicated at 74, 75 in Fig. 15. Upon the under surface of the upper side of the movable nose portion is secured a member 76, (Fig. 19), consisting of a V-shaped sheet of metal having outwardly extending flanges 77 upon opposite edges engaging the sheet metal covering 67. To this member 76 are secured the forward ends of rods 78 pivoted at their rear ends to bell crank levers 79 by which the rods 78 are operated to move the nose portion in or out. The forward ends of the sheet metal plates 13 are coiled into the cylindrical form shown at 80, the free edge being formed into a flange 81 secured to the inner surface of the plate as shown in Fig. 19. Plates 14 are turned backward in a similar fold 82 as shown in Figs. 2, 3 and 4.

The trailing portion of the aerofoil has sheet metal covering plates 83 secured to the ribs 42 and 44 from the extreme rear forward on the top and bottom surfaces to a point slightly forward of the rear edges of the sheet metal coverings 13 and 14 when the trailing portion is at its extreme limit of projection outward. These plates may each consist of a single sheet of metal folded on itself at the trailing edge. The manner of attaching the plates 83 to the ribs 42 and 44 is clearly shown in Figs. 24 and 29, the construction being substantially identical with that shown in Fig. 17, representing the manner of joining the sheets 13 to the rib 11. At their forward ends, the plates 83 are folded backward as indicated at 84 and 85 (Fig. 10) in a manner similar to the folding of the edge 80 shown in Fig. 19. The plates 13 and 14 are also bent forward in the manner indicated at 86 and 87 in Figs. 9 and 10 to provide a smooth flat surface for engagement with the upper and lower surfaces of the plates 83 as the trailing portion

of the aerofoil is projected and retracted. The retracted position is shown in Fig. 9, and the projected position is shown in Fig. 10. Upon the inner surface of the upper forward edge portion of the sheet 83 is secured a bracket member 88 as seen in Fig. 30, to which is pivoted at 89, a rod 90, the opposite end of the rod being pivoted to the bell crank lever 79.

The aerofoil may be made up in a series of panels of which the movable portions are independently movable. In Fig. 8, the end panel may have the bell crank levers 79 controlling its nose and trailing portions connected by a rod 91 with a lever 92 controlled by means of a hand wheel 93, and the panel 94 may have its bell crank levers 79 connected by a rod 95 controlled by a hand lever 96 operated independently of the wheel 93.

The operation of these movable nose and trailing portions of the outer panels to control the lateral stability of the airplane is explained in detail in my co-pending application previously herein referred to.

It will be apparent that, since the length of the arms of the bell crank levers 70 differ, the rods 78 being pivoted to the short arms of the levers and the rods 90 to the long arms, movement of the bell crank levers will result in a more rapid projection of the trailing portion than of the nose portion, and the extent of movement of the trailing portion will be approximately three times that of the nose portion. It will also be seen that in the retracted position of the nose portion shown in Fig. 3, the rear edges of the sheet metal covering plates 67 lie closely adjacent to the outer surfaces of the plates 13 and 14, and that as the nose portion is thrust forward to the position indicated in Fig. 4, the upper rear edges of the sheets 67 remain in close contact with the sheets 13, while the sheets 14 bend downward from a point a little to the rear of the leading spar 1, so that a substantially continuous curve is maintained upon both the top and bottom surfaces during the entire range of movement of the nose portion.

It will also be observed that the air pressure tends to force the rear end of the sheet metal 67 of the nose portion closely into contact with the lower surface of the sheet 14.

The trailing portion in the retracted position lies almost completely enclosed within the fixed central portion of the aerofoil, a small portion of the lower surface being exposed at the rear while in the closed position indicated in Fig. 9. The rib 42 is curved on an arc of a circle concentric with the curve of the guide tracks 37 and 38, so that as the trailing portion is projected to the rear, the upper surface of the sheet metal 83 remains in close contact with the

under surface of the folded portion 86 of the upper sheet metal covering 13. However since the upper and lower surfaces of the trailing portion diverge at an angle, as the trailing portion is projected from the position shown in Fig. 9 to that shown in Fig. 10, the lower surface of the sheet 83 sliding in contact with the upper surface of the folded edge portion 87 of the sheet 14 will cause the sheet 14 to be bent downward in a curve which begins at the point at which the flange 15 of the rib 12 is left free from attachment to the brace member 52. The lower surface of the plates 83 of the trailing portion will be formed on a curve which will be substantially a continuation of the curve formed by the lower surface of the sheets 14, so that the lower surface of the aerofoil at the rear has a substantially continuous curvature, the only break in this curvature being at the point where the folded portion 87 of the sheets 14 holds the sheets 14 a slight distance away from the plates 83. Since the sheets 14 overlap the lower outer surfaces of the plates 83, pressure of the air upon their lower surfaces will tend to hold the sheets 14 closely in contact with the plates 83. To relieve the friction between the lower surface of the plate 83 and the folded over portion 87 of the plate 14, the rollers 97 will be journaled at the rear end of the ribs 12, these rollers contacting at their periphery with the outer face of the locking strips 57 which hold the sheets 83 within the channeled ribs 44.

While the spars and ribs and the manner of attaching the sheet metal plates to the ribs have been shown in detail, illustration of the drift trussing has been entirely omitted, since this forms no part of the present invention, and may obviously be modified to suit different designs of aerofoils. It will be evident that with the present construction of ribs and spars the attachment of drift trusses may readily be accomplished.

The continuous longitudinal curvature of the upper sheet metal members 13 produces a lateral rigidity of the metal sheets between the ribs which substantially prevents sagging of the sheets transversely between the ribs, whereas in wings having a canvas covering, the tension causes the fabric to curve inward between the confronting edges of the ribs to produce a waved surface. This lateral rigidity of the sheet metal covering produced by its longitudinal curvature materially assists in securing rigidity of the aerofoil, and decreases the necessary weight of drift trussing.

The initial wing section in the present metallic construction will be chosen with a top camber upon its upper surface having a curvature at a point substantially midway between the forward end of the nose and the highest ordinate substantially coincident

with the arc of a circle, and the movable nose section will move forward and downward in an arc of a circle concentric with the arc forming a portion of the top surface, the shape of the forward portion of the nose being such that when the movable nose portion is at its point of extreme forward movement the upper surface of the aerofoil will be of substantially continuous curvature, and this curvature will be one which is efficient for slow speed. Considering for a moment only the upper surface of the aerofoil, it will be seen that it will be possible to choose an efficient camber for high speeds, a portion of which will be a substantially circular arc and that by extending the upper surface of the aerofoil along the circular arc, for a limited distance, a new curvature may be obtained adapted for the upper surface of an aerofoil efficient for flight at slow speed.

Considering the upper surface of the trailing portion of the aerofoil, it will be seen that when the movable trailing portion is projected along an arc of a circle concentric with the curvature of the guide tracks controlling this movement, there will be a slight discontinuity of curvature at the point which forms the trailing edge of the aerofoil in its initial position, with the movable trailing portion fully retracted, but this double camber toward the rear of the trailing portion has been found to produce an efficient chamber for slow speed, the effect of the double camber apparently being to assist in preventing movement of the center of pressure with changing angle of incidence.

Considering the lower surface of the aerofoil, it will be seen that a relatively high camber suitable for slower speeds may be obtained with substantially no discontinuity of curvature by providing a fixed central portion having flexible covering plates at the front and rear of the fixed portion, the flexure of which will be co-incident with the downward and outward movement of the nose and trailing portions, and that the curvature of the flexible metallic covering may be made to co-operate with the curvature of the lower surfaces of the nose and trailing portions by providing a graduation of the resiliency of the metallic ribs supporting the covering plates. Having chosen a curvature for the lower surfaces of the aerofoil, suitable for co-operation with the curvature obtained upon the upper surface by the extension of the movable nose and trailing portions, this curvature of the lower surface may readily be produced by making the lower surface of the trailing portion of the curvature selected and then causing the curvature of the flexible covering sheets connecting the trailing portion with the fixed central portion to assume

the desired curvature by a suitable adjustment of the rigidity of the supporting ribs, this adjustment of rigidity being attained by suitably varying the width of the flanges upon the upper surface of the ribs.

A curvature for the lower surface of the aerofoil will be chosen such that a portion somewhat in advance of the center of the chord will be co-incident with the curve forming the lower portion of the initial section. The curvature of the lower portion of the nose will be one which will produce an efficient section for the nose portion in either its projected or retracted position. The lower surface of the trailing portion can of course be made of any desired configuration, and the spaces between the movable nose and trailing portions and the fixed central section will be bridged by flexible sheets, the curvature of which may be regulated by proper adjustment of the rigidity of the supporting ribs at various points throughout their length.

By the structure herein described, an increase in area may be obtained amounting to upwards of thirty-three per cent without undue increase in weight, and furthermore this increase in area, while giving increased lift, is not attended by discontinuity of curvature and loss of efficiency as in certain devices hitherto proposed. The change in camber which in certain other types of variable camber aerofoils is attended by great increase in resistance, is in the present device produced with a minimum discontinuity of curvature, with an increase in area, and with an increase in the angle of incidence, all of which produce increased lifting power, while avoiding an accompanying change in the angle of the axis of the propeller which would result in lower efficiency. While the chord increases, the maximum ordinate, in the position in which the nose and trailing portions are fully extended, lies at about the same percentage of the chord from the front as the maximum ordinate lies when the aerofoil is in the configuration produced by the retraction of the movable portions. The center of pressure will thus not be moved greatly to the rear because of the greater projection of the trailing portion, and this tendency to rearward movement will be balanced by the tendency to forward movement of the center of pressure due to the increase of the angle of incidence.

Not only has the angle of incidence been changed, but the chord has been increased and the camber greatly modified, so that with the increase in area and deeping of the camber, in addition to the increase in angle, the lift has very greatly increased while the center of pressure has remained at substantially the same position with respect to the center of gravity of the machine.

Complete projection of the trailing portion lowers its rear edge below the lower edge of the nose portion to increase the angle of incidence by about four degrees in the configuration shown, without changing the angle of the fuselage. This angle of incidence may of course be increased in the usual way by tilting the fuselage until the desired lift is reached, but the amount of tilt necessary will be approximately one-third less than if the wing had no outwardly extensible portions.

For climbing, the aviator may start from rest with the nose and trailing portions fully retracted to decrease the resistance to the minimum. This will give the high speed section with the minimum camber and the minimum angle of incidence. Thus the airplane may quickly attain such speed in running along the ground for a short distance that if the nose and trailing portions are rapidly projected, the increased area, increased camber, and increased angle of incidence will produce substantially instantaneously a sufficient lift for take-off at the speed already attained, thus shortening the necessary travel along the ground.

After the airplane has reached a sufficient height, the movable nose and trailing portions of the central panel or panels of the aerofoil will be retracted without changing the position of the movable portions of the outer wing panels. The central portion of the aerofoil will thus assume a camber for higher speed, and as the speed increases, the operator may move the lever to retract the movable portions of the outer wing panels to the fully retracted position, so that the entire aerofoil will be given the most efficient camber for high speed. At the same time, lateral stability may be obtained by such slight movements of the controlling means as are necessary to project the movable portions upon either wing to vary the lift.

For landing, the nose and trailing portions will be brought to the fully projected position, giving an increase in wing area of approximately thirty-three per cent with the sections herein illustrated. At the same time the fuselage will be given the necessary tilt to produce the angle at which the lift is greatest.

After the wheels have come into contact with the ground, the nose and trailing portions will be retracted to decrease the lift and thus the weight of the machine will be thrown upon the wheels, whereby brakes upon the wheels will be rendered more efficient. If however the aviator wishes to utilize the resistance due to the large wing area at a high angle of incidence to check movement under favorable wind conditions, the movable portions may be left projected to their outer limit, with the aerofoil tilted to the maximum angle of incidence.

From the foregoing description, it will be apparent that there has been provided an aerofoil in which the stream line of the cambered surface is not maintained, but in which the configuration is varied from a form efficient for high speed to a form efficient for high lift at low speeds. The variation in the chord produced by retraction of the movable portion will of course cause a change in the aspect ratio, the higher aspect ratio at high speed and at low angles giving a better lift/drift ratio, while the curvature of the upper surface of the trailing portion is not similar to that of the top of the fixed section, but is an arc of a circle, and while the curvature is not maintained as the trailing portion is projected, actual wind-tunnel tests have also demonstrated that the double camber of the upper surface produced when the trailing portion is projected is highly efficient. These tests have also demonstrated that the camber of the upper surface of an aerofoil may consist in part of arcs of circles at the forward and rear portions in a highly efficient section.

It will be obvious that many changes may be made in the details of construction of the various portions of the airplane with changes in design without departing from the principle of the invention herein set forth or sacrificing any of its advantages. The invention is therefore claimed broadly within the legitimate scope of the appended claims.

I claim:—

1. An aerofoil having a member channeled in cross section, a pair of metal covering plates having their adjacent edges interlocked with the walls of the channel within the interior of said channel, and a locking strip in said channel to hold said edge portions of said plates in interlocking engagement with the channel walls.

2. An aerofoil having a member of channel form in cross section, a pair of metal covering plates having their adjacent edge portions folded over the side walls of said channel and extended within the interior of said channel, and a removable locking strip in said channel holding said edge portions with said channel wall within said channel.

3. An aerofoil having a member of channel form in cross section, the free edges of the side walls of the channel being bent inwardly of the channel to form inwardly extending flanges, a pair of sheet metal covering plates having their adjacent edge portions inbent into the channel, and around the free edges of said flanges, and a locking strip having portions disposed within the channel to hold said edge portions interlocked with said flanges.

4. An aerofoil having a member of channel form in cross-section, the free edge por-

tions of the side walls of the channel being formed inwardly of the channel toward each other to provide interior flanges on the channel, a pair of sheet metal covering plates having their adjacent edge portions extending into the channel with said edge portions bent to engage around the free edges of said flanges, and a locking strip within the channel engaging the edge portions of the plates engaged around the flanges to prevent withdrawal of the sheet metal plates and spreading of the channel.

5. An aerofoil having a member formed of sheet metal bent into channel form in cross section, the free edge portions of the side walls of the channel being inbent to form flanges extending substantially parallel with each other within the channel, a pair of covering plates of sheet metal having their adjacent edge portions bent inwardly between the flanges and around the free edges thereof, and a locking strip within the channel, said strip having portions engaging between said flanges and between said flanges and the side walls of the channel to prevent separation of the flanges.

6. An aerofoil having a rib cap-member of sheet metal formed as a channel, the free edges of the sheet metal being formed as flanges extending toward the interior of said channel and the metal of said cap-member upon the side of the channel opposite said flanges being folded to form a flange extending centrally of the back of the channel and longitudinally thereof.

7. In an aerofoil, a rib cap-member formed as an open channel, the metal at the open side of the channel being provided with flanges extending toward the interior of the channel and the opposite outer surface of the channel being provided with a central flange extending away from the channel, sheet metal covering plates having their free edges bent to engage with the flanges within said channel, and a brace member having terminal portions engaging opposite sides of the central flange and secured thereto.

8. In an aerofoil, a sheet metal member of channel form in cross section with the edge portions of the side walls of the channel extended inwardly of the channel and partially closing the open side of the channel, sheet metal covering plates having their adjacent edge portions inbent over the inwardly extending edge portions of said channel walls within the channel member, and a locking strip fitting within and filling the channel and held therein by said inbent edge portions of said channel walls, said strip being endwise removable from said channel to release said edge portions of said plates.

9. In an aerofoil, a member of open channel form in cross section, the free edge portions of the side walls of the channel being extended inwardly to form flanges extend-

ing toward the interior of the channel, sheet metal covering plates having their free edges bent upwardly and around the free edges of said flanges within said channel, a locking strip fitting within said channel and formed with a portion extending between said flanges through the open side of said channel and portions within said channel between said flanges and the side walls of the channel to lock the edges of the plates in place therein and to hold the channel walls against spreading under strain of the plates thereon.

10. In an aerofoil, a rib cap-member formed as an open channel, a flexible sheet metal covering plate having its edge secured within the channel in the said cap-member, said cap member having a longitudinal flange at substantially right angles to the covering plate, said flange varying in width longitudinally of the rib cap member whereby to provide varying resistance to bending of the cap member and of the metal covering plate.

11. In an aerofoil wherein a metallic covering plate is flexed during change of section of the aerofoil, a member secured to said plate having a flange at substantially right angles to said plate, said flange being of graduated dimensions to provide unequal resistance to flexure whereby the curvature of the plate is graduated.

12. In an aerofoil, a spar comprising sheet metal side and edge portions, a channeled rib cap-member mounted transversely of the edge portion of said spar, with the surface of the rib cap-member opposite the open side of the channel lying in contact with the edge portion of the spar and secured thereto.

13. In a metallic aerofoil, a spar, a rib cap-member of channel form in cross section having a longitudinal flange extending outwardly from the bottom wall of said channel, said cap-member lying transversely of said spar, said rib being cut away opposite said spar to permit the closed side of said channel to contact and be secured to the spar, and a brace member within the angle between said cap-member and spar consisting of a sheet metal plate folded upon itself to form substantially parallel members embracing said flange and secured thereto, said brace member being also provided with flanges engaging the spar and secured thereto.

14. In a metallic aerofoil, a spar comprising sheet metal side plates, an upper plate and a lower plate, said upper and lower plates having flanges engaging the edges of said side plates, channeled metallic rib cap-members mounted transversely of said upper and lower plates with the surface of the channeled cap-members opposite the open side of the channel lying in contact with the face of the top and bottom plates, said chan-

neled cap members having flanges on the side opposite the open channel, said flanges terminating upon opposite sides of the spar, and brace members secured to the side plates of the spar and to the flanges of the channeled cap-members.

15. A structure as in claim 14, in which the spar has an interior base member consisting of a sheet of metal secured to the inner faces of the side plates opposite the point of attachment of said first mentioned brace members.

16. A metallic aerofoil comprising a metallic spar, a metallic channeled rib cap member secured thereto and extending rearward, a metallic rib member also secured to said spar and extending forward and a second channeled rib cap member secured at its rear end to said rearwardly extending rib cap member and lying beneath said forwardly extending rib cap member, and sheet metal covering plates engaging within both of said channeled members.

17. A metallic aerofoil comprising a metallic spar, a metallic channeled rib cap member secured to the spar and extending beyond the same, metallic rib trussing forming together with the cap-member a rib secured to the spar and extending beyond the same, a movable rib portion beyond the spar, guide rollers carried by said movable rib portion, a track for said rollers upon said extended portion of said fixed rib, said track having its curvature disposed to cause upward and downward movement of the movable portion of the rib, said movable rib portion having engagement with a free end portion of said cap-member, whereby the same is flexed by the movement of the movable rib portion.

18. In an aerofoil, a metallic rib member comprising fixed and movable portions, said fixed portion being formed with a channeled portion, with the edges of the channeled portion forming a guide track adapted for engagement with guide rollers, and said movable portion of said rib member being provided with a bracket portion carrying grooved guide rollers journaled thereon to engage said guide tracks.

19. In an aerofoil, a rib member comprising a fixed portion and a movable portion, said fixed portion including oppositely arranged sheet metal members secured together and having portions of their confronting surfaces formed into curved channels, the inner edges of the channels constituting curved edge tracks adapted to be engaged by diametrically opposite portions of grooved rollers, and said movable portion of the aerofoil having grooved rollers engaging said curved guide tracks.

20. In an aerofoil, a fixed portion and a movable portion, said fixed portion having a channeled part, the edges of the channeled

part forming a curved guide track adapted for engagement with the curved peripheries of guide rollers, and the movable portion of said aerofoil having a bracket portion provided with grooved guide rollers journaled thereon engaging said guide track, the outer edges of each of said portions having sheet metal covering plates secured thereon, said edges being formed in curves substantially parallel to the curve of said guide tracks, whereby during movement of the movable portion guided by the engagement of the rollers with the guide tracks, the distance between the metal covering plates upon said fixed and movable portions will remain substantially constant.

21. In a metallic aerofoil, a movable nose portion having sheet metal cap members, a channeled rib member supported upon the upper edges of said sheet metal cap members, sheet metal covering plates bent upward adjacent to their meeting edges and having their free edges secured within said channeled cap members, and a strengthening plate secured to the sheet metal rib members and to the covering plates, the strengthening plate together with the upwardly bent portions of the covering plates and the cap members constituting curved strengthening ribs elevated above the general surface of the sheet metal covering plates.

22. A metallic aerofoil provided with a movable nose portion and a movable trailing portion, each portion having means whereby it is guided outward and downward in a curved path; the rear part of the upper surface of the nose portion and the upper surface of the trailing portion being substantially concentric with said curved paths respectively whereby the rear edge of the movable nose portion and the rear edge of the relatively fixed portion are maintained at substantially equal distances from the upper surface of the relatively fixed portion and the upper surface of the movable trailing portion, respectively, during movement of the nose and trailing portions, the lower surface of said movable nose portion overlapping the flexible metal plates constituting the lower surface of the relatively fixed portion and having sliding connection therewith, and the lower surface of the trailing portion pressing down upon the flexible plates constituting the lower rear covering of the relatively fixed portion, whereby forward and downward movement of the nose portion and rearward and downward movement of the trailing portion will cause flexure of the lower metallic covering plates to form a substantially unbroken curve from the tip of the nose to the rear edge of the trailing portion on the top and bottom surfaces of the aerofoil.

23. An aerofoil comprising a fixed por-

tion and a movable portion forming an edge portion of the aerofoil, metallic covering plates secured to said fixed portion throughout a part of the length of said fixed portion and free therefrom adjacent the movable portion of the aerofoil, said plates forming the lower covering of the aerofoil, and plates secured to the movable portion to form the lower surface thereof, the adjacent edge portions of said plates on the movable portion and the unsecured edge portion of the plates on the fixed portion being in overlapping relation, said movable portion being movable downwardly to change the camber of the aerofoil and to flex the unsecured portion of said plates to change the continuous curvature to the lower surface of the aerofoil.

24. An aerofoil having metallic covering plates upon its lower surface connected at their adjacent edges by flexible metallic rib members, said rib members being rigidly secured at their forward end and free for downward movement at their rear end, each rib member being formed with a longitudinal flange, the width of which gradually tapers from a point near the center of the lower surface of the aerofoil toward the rear, whereby the rib member is more rigid at its forward end and gradually decreases in rigidity toward the rear so that pressure upon the rear end of the rib will cause a curvature change throughout the free portion of the member as the rear portion is depressed.

25. An aerofoil having a fixed wing portion having a constant top camber and a variable bottom camber, and having a flex-

ible lower covering, a movable nose portion having the camber of the rear part of its top substantially parallel with the curvature of the front part of the top of the fixed section and being movable parallel therewith, and having its lower surface movable from a positive to a negative angle, and a trailing section having its top formed on a circular arc and movable along said arc to maintain uniform distance from the top covering of the fixed portion, the lower surface of trailing portion engaging the flexible lower covering of the fixed portion as it moves outward to cause it to curve downwardly, the flexibility being graduated to predetermine the curvature at various points of outward movement of the trailing portion.

26. An airplane having an initial contour designed for high lift/drift ratio and having forwardly and rearwardly slidable portions, the front portion being slidable over a fixed portion, the rear portion being slidable within the fixed portion having a flexible lower covering, each movable portion engaging the flexible lower covering of the fixed portion to cause downward curvature thereof at front and rear, whereby to cause a change of section from an initial high-speed section to an efficient low-speed section of greater area, and deeper camber.

In testimony whereof I affix my signature in presence of two witnesses.

JOHN F. COOK, JR.

Witnesses:

ARTHUR MINNICK,

G. L. TERNA.