TECHNICAL MEMORANDUMS

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 432

SLOTTED-WING AIRPLANES

By E. Everling

From "Zeitschrift des Vereines deutscher Ingenieure"
May 7, 1927

Washington
October, 1927

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

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SLOTTED-WING AIRPLANES.*

By E. Everling.

Air traffic is swift traffic. An airplane must continuously perform gainless work just to keep itself in the air. Hence, it has a greater, more unfavorable L/D ratio than an airship, water craft or land vehicle of any kind, whose weight is supported without the expenditure of its own energy, because the airplane must overcome a greater head resistance in proportion to its own weight. This entails greater operation costs and higher transportation charges, which must be offset by the advantage of the greatest saving of time.

Air traffic is swift traffic for still another reason. While in all other kinds of traffic the driving energy increases with the third power of the resistance (except that wheel resistance increases more slowly), the requisite flight energy increases, within certain limits, only in direct proportion to the flight speed. Since the fuel consumption is proportional to the flight time and the engine power, it is, within the same limits, independent of the speed, in contrast with all other vehicles of traffic. Therefore, if its speed could be increased at will, the airplane would excel, even in economy, all its water or earthbound competitors.

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*"Spaltflügel-Flugzeuge," from "Zeitschrift des Vereines deutscher Ingenieure," May 7, 1927, pp. 645-647.

Thirdly, air traffic must be swift traffic, because the greater its speed, the more independent it is of the currents of the atmospheric ocean and the more closely it can conform to a precise schedule.

There are various obstacles, however, to increasing the speed. In the first place, an airplane requires more powerful, and consequently, heavier engines, whose additional weight must be at the expense of the pay load or the fuel supply, thereby reducing the flight distance. Above all, however, the greater speed of the airplane (whose utilization is still further promoted by the choice of the direct air line without reference to the nature of the ground and the distribution of land and water) only effects an actual saving in the travel time when the airports are not located too far from the traffic centers, i.e. when it doesnot take too long to get to them. In the vicinity of large cities, however, the ground is so valuable, that only small spaces are available for aviation fields. Hence, commercial airplanes should have a low landing speed, so as to be able to land or take off with only a short run. The same requirement holds for intermediate or emergency landings, so that the apparently paradoxical saying that "flying is landing" still holds true.

The demand for a lower landing speed is, however, incompatible with the natural demand for a higher flight speed. If the power and, consequently, the weight of the engine are not to be excessively increased, great speed must be obtained through a low-wing loading which, in its turn, sets a lower limit to the landing speed. While flight is ordinarily at lift coefficients of less than 0.5, ordinary wing sections give no maximum lift greater than 1.8 and well-streamlined shapes give still less. Hence, the so necessary speed range is narrowly limited. Increasing the angle of attack avails nothing here. Under ordinary flight conditions, the lift coefficient increases first in proportion to the angle of attack of the air current, and then in a smaller ratio until its maximum value is reached at about 15°. If the angle of attack is further increased, the flow becomes detached, the lift decreases and the airplane falls. The detachment or separation is due to the fact that the air in the boundary layer is retarded and loses its momentum, so that, behind the thickest part of the wing where the velocity must be again converted into pressure, it can no longer overcome the external counterpressure.

Hence, there are two ways for increasing the speed range, so important from the commercial viewpoint. The first is to make the real flight at a high altitude, as compared with the take-off and landing altitude, and hence in rarer atmosphere where the speed is greater for a given wing loading and where a more economical angle of attack can be maintained. This way is not feasible, however, till high-altitude engines have been further developed. Near the ground the flight speed, with retention of the same landing ability, can be increased only by reducing the wing loading and simultaneously diminishing the maximum lift coefficient. This can be done by preventing the separation of the flow on increasing the angle of attack. For this purpose, energy must be communicated to the boundary layer.

In order to accelerate the boundary layer, a layer of air might be blown out through a slot in the suction (upper) side of the wing. This would, however, require a pump, which would generally be operated by the engine, so that it would not be available at the very time when it would be most needed, namely in the event of a forced landing with the engine stopped. Or, one might use a different wing section or profile during swift flight, than when taking off or landing, i.e., employ a wing with a variable camber.*

A third way consists in transmitting energy to the boundary layer on the suction side of the wing, where the tendency to separate is the greatest, from a point where the velocity is smaller and the flow energy in the retarded boundary layer is manifested in the form of pressure. This is the case in the immediate vicinity of the critical point on the pressure side of the wing. It is only necessary to provide channels through the wing and to see that the flow resistance in them is not too great. Air will then pass from the pressure side to the suction side of the wing, thereby converting its energy into velocity and communicating the

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*H. Herrmann, "Zeitschrift für Flugtechnik und Motorluftschiffahrt," May 31, 1921, p.147.

latter to the boundary layer, so that it will not separate till later, at a greater angle of attack, and thus enable the augmentation of the angle of attack with a corresponding increase in the maximum lift.* In practice, these channels must take the form of slots, owing to the lateral extension of the state of flow.

The correctness of this assumption is demonstrated by Figs. 1-3, in which the coefficients are 100 times the usual values for the wing loading divided by the dynamic pressure. For the slotted wing, in comparison with the Göttingen profile 422, the maximum lift rose from 1.36 at an angle of attack of 14.5° to 2.18 at 26.2°, because three slots transmitted flow momentum from the pressure side to the boundary layer on the suction side.** Simultaneously the drag increased from 0.19 to 0.41, which is more than double for the wing itself or about one-half for the whole airplane. This is entirely comprehensible, for the transfer of energy to the boundary layer must be made at the expense of the flow energy. This drag is not so very harmful, however, because in the flattening out before landing, a greater drag is just as important for the diminution of the landing place as the shortening of the actual landing run. Since, however, the minimum drag simultaneously increases from 0.02 to 0.045, which is considera-

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*A. Betz, "Die Wirkungsweise von Unterteilten Flügelprofilen" from "Berichte und Abhandlungen der Wissenschaftlichen Gesellschaft für Luftfahrt," Jan., 1922, p. 23. (For translation, see N.A.C.A. Technical Note No. 100.)

**Wieselsberger, "Untersuchungen über Tragflügel mit unterteiltem Profil," from "Ergebnisse der Aerodynamischen Versuchsanstalt zu Göttingen," Report II, 1923, pp. 55-64. (For translation, see McCook Field Memo Report No. 124.)

ble, even with the inclusion of the structural drag, the use of the slotted wing is of advantage only when it is possible to restore the usual shape of the wing section (Fig. 2) in ordinary flight. This is very difficult to do in flight with a triple-slotted wing section under the great stresses to which the wing is subjected by the bending moments.

Lachmann*, the inventor of the slotted wing has, however, indicated a way for the technical application of this principle which, in its most recent form, not only diminishes the drag increase in ordinary flight, but also improves other disadvantages of the large angle of attack, namely excessive inclination of the fuselage and excessive rearward shifting of the center of pressure and the attendant disturbance of the flight stability. To the leading edge of the main wing, which has about the shape of an ordinary wing section, there is fitted an auxiliary wing of sheet aluminum in such manner that it ordinarily forms an extension of the leading edge, but can be raised in landing, so as to increase the lift, as shown in Figs. 4-6. The position 3d in Fig. 5, indicates the closure of the upper end of the slot, whereby nothing is gained, however. Fig. 6 shows that the moment about the leading edge, which is dependent on the lift, is kept small by pushing the auxiliary wing forward, thus avoiding the rearward shifting of the center of pressure (intersec-

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*"Neuere Versuchsergebnisse mit Spaltflügeln," "Zeitschrift für Flugtechnik und Motorluftschiffahrt," May 26, 1924, pp. 109-116. (For translation, see N.A.C.A. Technical Memorandum No. 282.)

tion point of the wing chord and the resultant of the air forces) due to the great increase in the angle of attack, and improving the equalization of the moments and the static longitudinal stability in landing, an advantage which does not even need to be procured at the expense of a complicated device for opening the front slot. Since the pushing forward of the auxiliary wing also increases the wing area, it means a slight further diminution of the landing speed.

Since an angle of attack of 26°, for obtaining a lift coefficient of 1.95 (Fig. 4) means an excessive inclination of the fuselage in flying horizontally, and consequent undesired landing on the tail, such a slotted wing must either be made adjustable as a whole (which principle has hitherto been successfully applied only to gliders), or be reduced to a simple form of adjustable profile. Lachmann attaches to the trailing edge of the wing throughout its whole span, in addition to the customary ailerons, flaps which in landing can be pulled downward to increase the angle of attack of the wing itself and also the wing camber, thereby further increasing both the lift and the stability. Between the main wing and the flap there is also a slot which supplements the action of the auxiliary wing.

In recent years these principles have been applied to a number of German airplanes and to a few airplanes of other nationalities. Fig. 7 shows the Junkers low-wing monoplane, construction type T.29, which has a flap on the trailing edge with a strong slot effect, with the slot open in the landing position ("Luftfahrt," Vol. 29, 1925, p. 270). Heinkel has also utilized the slot effect on the trailing edge in two construction types.

The auxiliary wing on the leading edge and the flap on the trailing edge are joined, thus forming a sort of three-part wing section, in an experimental airplane of Udet ("Illustrierte Flugwoche," Vol. 7, (1925), p. 477), in which a rotary rod, running throughout the length of the wing and operated by the pilot, pushes the auxiliary wing forward and simultaneously depresses the rear flap. The Albatros newspaper and commercial biplane (Fig. 8), which has this device on both wings, works the same way.*

Handley Page, the English airplane builder who, independently of Lachmann, developed the same principle somewhat later and who is collaborating with the German inventor, has recently adopted a very similar device in his three-engine "Hamlet" high-wing monoplane (Figs. 9-12) ("The Aeroplane," Vol. 31, 1926, p. 504). A rotary tube pushes forward the supports which are jointed to levers (Fig. 11) and simultaneously pulls down the rear flap by means of connecting rods (Fig. 9), which are jointed to slotted double bell-crank levers by smaller levers (Fig. 10).

So simple as these devices are, they still entail an increase in weight and a complexity in the wing structure which,

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*Lachmann, "Zeitschrift für Flugtechnik und Motorluftschiffahrt," Vol. 15 (1926), p. 199; and "Illustrierte Flugwoche," Vol. 8, (1926), p. 172.

at the present time, are not sufficiently offset by the gain in lift. Even if the lift coefficient be raised from 1.4 to 2.2, the landing speed is thereby reduced only in the inverse ratio of the square roots, or about 20%. When it is considered that the momentum, which has to be destroyed during the taxying, decreases in the ratio of the lift coefficients themselves, or about 36%, the gain is not very great. It cannot, however, be demanded of a technical innovation, which opens hitherto impassable ways, that it lead immediately to the desired goal.

A very advantageous application of the slotted-wing principle, likewise rightly recognized by Lachmann* is afforded in the field of steering. If the ailerons are provided with slots, which open when the ailerons are depressed, but close when they are raised, the flow will closely conform to the arched wing (Fig. 13), but will separate, on the contrary, from the broken profile (Fig. 14), thus producing a greater lift in the former case and a smaller lift in the latter case than with the ordinary arrangement. The result is that the ailerons, even at large angles of attack at which the speed is low and there is danger of going into a spin, not only retain their efficacy but can also prevent autorotation** by the difference in the lift at the wing tips.

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*Lachmann, "Stall-Proof Airplanes," "Berichte und Abhandlungen der Wissenschaftlichen Gesellschaft für Luftfahrt," May, 1926, pp. 86-90 (N.A.C.A. Technical Memorandum No. 393).

**At large angles of attack, the air forces are so distributed that many airplanes tend to rotate around their longitudinal axis (autorotation). The axis of rotation tends to shift to the airplane axis (maximum inertia moment), thereby maintaining a greater angle of attack, accompanied by diminished maneuverability and a condition of spin.

Although the slotted wing offers advantages for the steering and for lessening the landing speed, it cannot yet be said to afford a solution for the problem of the small landing field. Even should the maximum lift of 1.4 be increased not only by the small fraction thus far attained, but even a hundredfold, the landing speed of a moderately swift airplane would thereby only be reduced from 100 km (62 miles) per hour to 10 km (6.2 miles) per hour, hence still so swift that jumping off would be dangerous. This would not enable one to land safely on a house roof, entirely aside from wind disturbances. Here we must have ground arrangements, as occasionally recommended but not yet obtained in practical form. In this connection, a wide and promising field of activity lies open to the imagination of the engineer.

Translation by Dwight M. Miner,
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for Aeronautics.

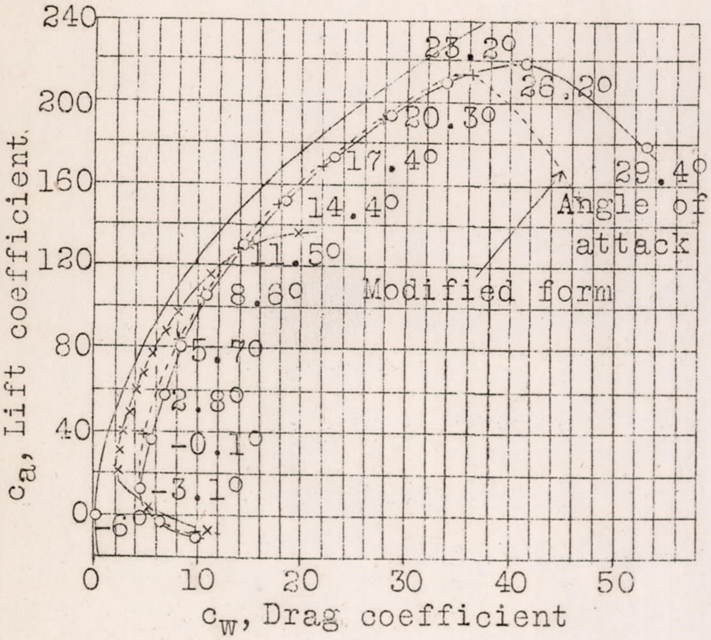

Fig.1

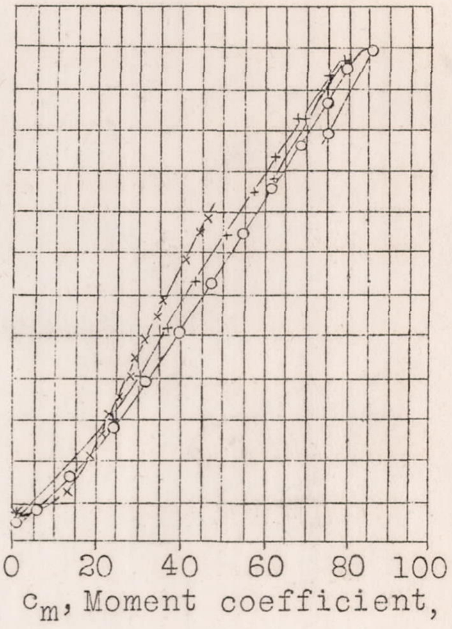

Fig.3

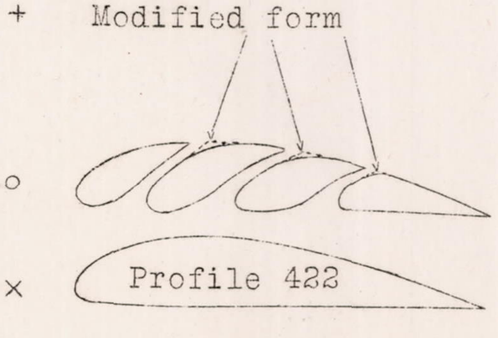

Fig.2.

Fig.1,2,3. Functioning of a multi-slotted wing in comparison with the Göttingen profile 422.

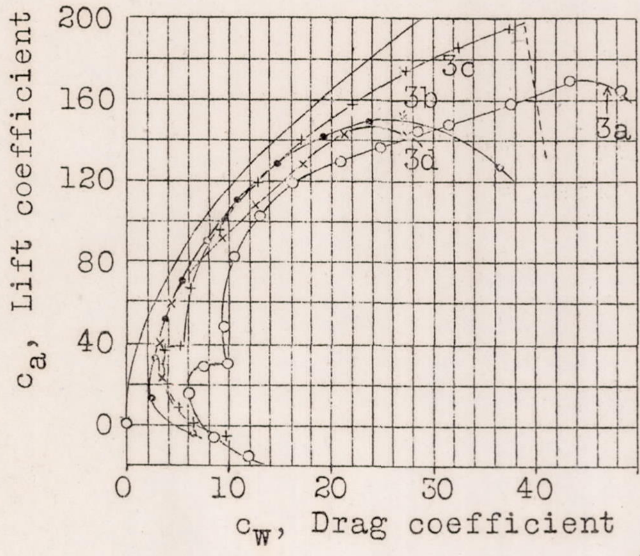

Fig.4

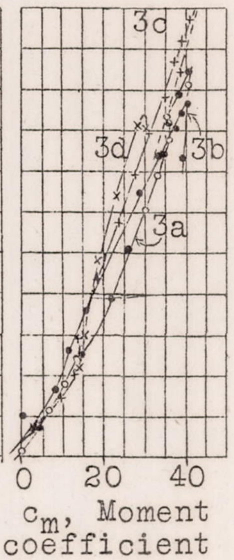

Fig.6

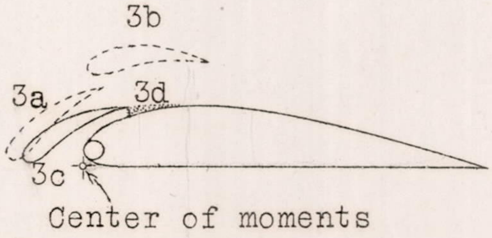

Fig.5.

Figs.4,5,6 Functioning of a wing with various auxiliary wings.

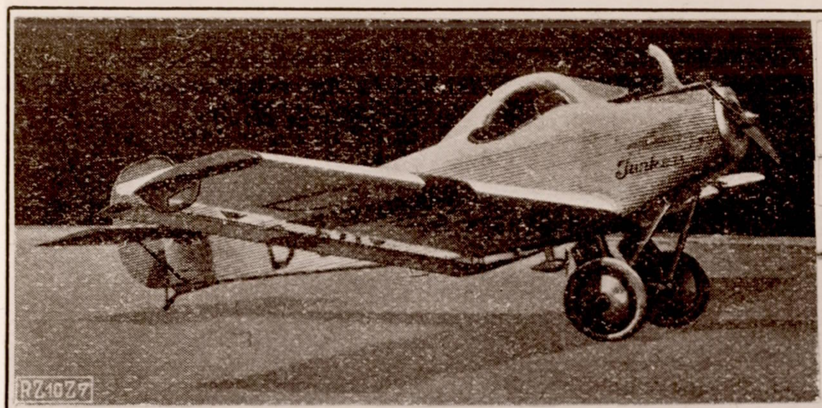

Fig.7 Junkers low-wing monoplane T29 with slot and auxiliary wings on the trailing edge, in landing position with open slot.

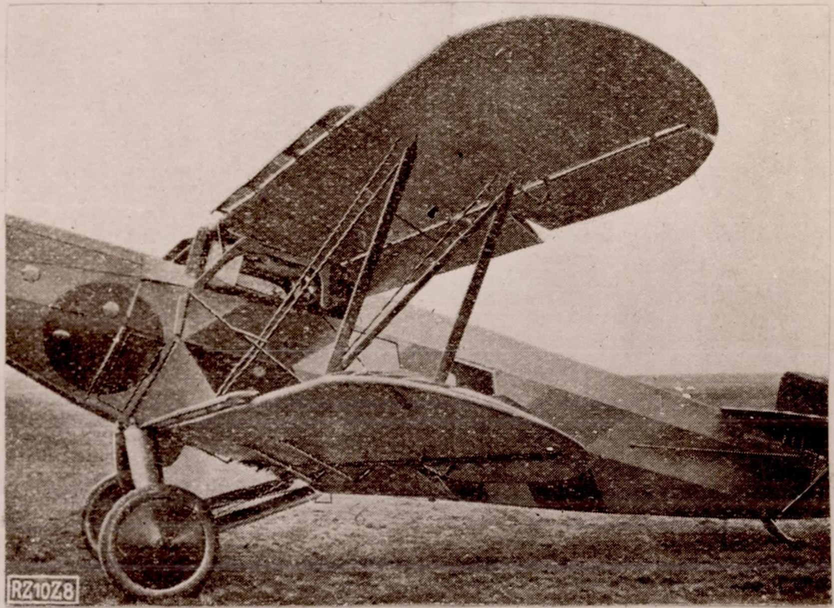

Fig.8 Newspaper airplane Albatros L72a with auxiliary wings on leading edges and adjustable flaps on the trailing edges, in starting & landing position

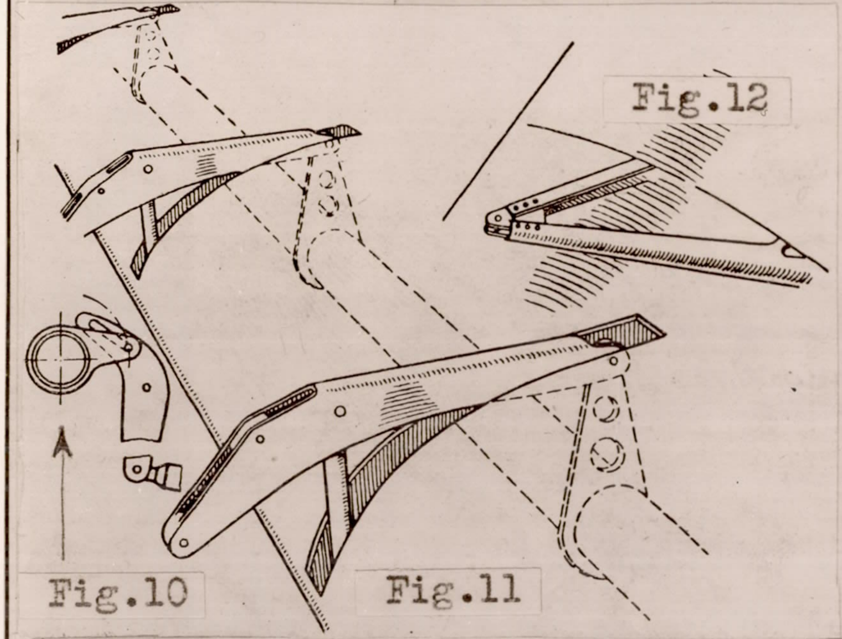

Fig.10

Fig.11

Fig.12

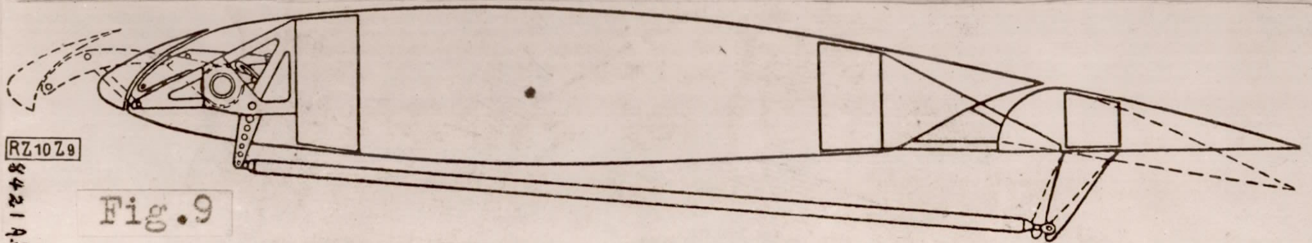

Fig.9

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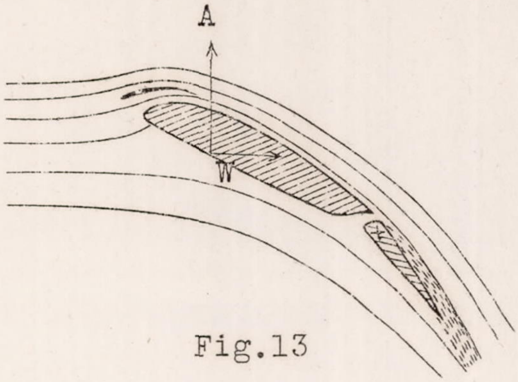

Fig.13

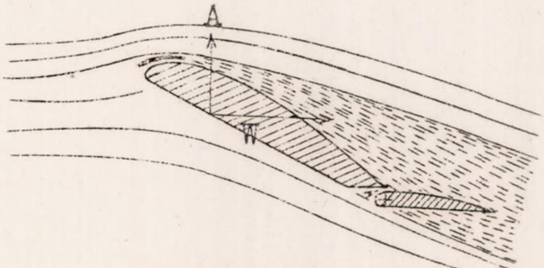

Fig.14

Figs.13,14 Increasing the effect of an aileron by an auxiliary wing with intervening slot. Contrast between lowered and raised aileron.