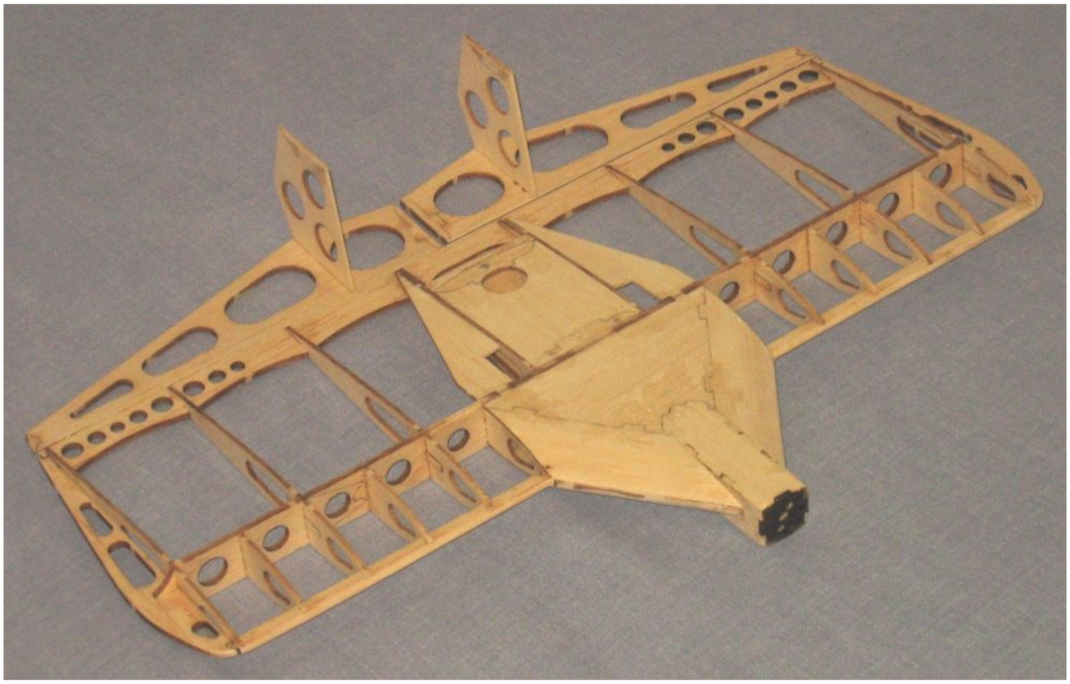
No. 301 **JULY 2011**

T.W.I.T.T. NEWSLETTER



This is the Quick Wing that is electric powered with or without the vertical fins. From MySpace.com

T.W.I.T.T.
The Wing Is The Thing
P.O. Box 20430
El Cajon, CA 92021

The number after your name indicates the ending year and month of your current subscription, i.e., **1107** means this is your last issue unless renewed.

Next TWITT meeting: Saturday, July 16, 2011, beginning at 1:30 pm at hanger A-4, Gillespie Field, El Cajon, CA (first hanger row on Joe Crosson Drive - Southeast side of Gillespie).

THE WING IS THE THING (T.W.I.T.T.)

T.W.I.T.T. is a non-profit organization whose membership seeks to promote the research and development of flying wings and other tailless aircraft by providing a forum for the exchange of ideas and experiences on an international basis. T.W.I.T.T. is affiliated with The Hunsaker Foundation, which is dedicated to furthering education and research in a variety of disciplines.

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Members only section: ID – **20issues10**
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Meetings are held on the third Saturday of every other month (beginning with January), at 1:30 PM, at Hanger A-4, Gillespie Field, El Cajon, California (first row of hangers on the south end of Joe Crosson Drive (#1720), east side of Gillespie or Skid Row for those flying in).

TABLE OF CONTENTS

PRESIDENT'S CORNER

Well, another issue in the can although you might have gotten it a couple of days late. I sort of lost track of the due date as the first weekend of the month rapidly approached and I got tied up with a multitude of other projects.

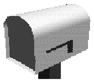
I noticed when I started putting it together that I had mislabeled the Weyl article as Part IV instead of Part V in the last issue and it was pointed out by Gavin as he read through that issue. I have included a short note at the beginning of Parts VI and VII letting everyone know that none of the parts were missed.

While no one has asked about the references that are made in the various parts, there is quite an extensive listing at the end. There wasn't enough room in this issue to include it, so it will be part of next month's issue.

Not many e-mails or letters this month but there is a backlog of Nurflugel and Mitchell U-2 material coming in so I will probably use the next issue to get caught up on that stuff unless I get something more interesting in from one of you. I also have some more Weyl papers to scan and put in a series of issues and I hope you find this historical view of flying wings enjoyable and useful information.

I am hoping to have some time in late summer to start pulling items from the archives and using them as filler or complete articles in the coming issues. We have some very unique stuff in the files and I know you will find it quite interesting. But this doesn't mean you shouldn't be sending me what you have since it would probably we something more current and that is also great.

Andy



LETTERS TO THE EDITOR

June 14, 2011

Just wondering if the info on the Opal is still available. I actually knew Scott's dad Colin back in the Grasshopper days.

Cheers,

Colin Hopkins
<colinhopkins1@gmail.com>

(ed. – I responded with: As far as I know everything that is available can be found through searches on the Internet. We have a little bit on our site and there are other pictures and some story lines in the public area, but you just need to be persistent in using different words to try and find it." If anyone has more information that could be provided please send it along to Colin and make sure to copy TWITT so we can share it with the other members.)

June 21, 2011

I am finishing a flying wing, designed by Reimar Horten in Cordoba, Argentina. It is very similar to the PUL-10 German design. I tried to communicate with someone who has an update on the PUL-10, because what appears on the Internet is a number of years old.

Thanks

Daniel Rodriguez
<djr_cba@hotmail.com>

(ed. – I replied with: "Below you can see some discussion from March on this subject and at the bottom an e-mail address you can use for contacting Mr. Mattlener.

If you come up with anything new beyond what Karl Senn has said below, please let me know so I can share it with my members."

I got the following back from Daniel: "Thank you very much, your email has been helpful. I suspected that the PUL-10 had those problems and now I´ve confirmed.

I would be grateful to you if you could send me more details on the flying wing or something similar. I guess that in three months I could have my first flight. I promise to send photos, videos and audio data, whenever he flies. Very grateful!"

Daniel)

(Note: The previous part in the June issue was labeled at Part IV when it should have been Part V, so you haven't missed a part.)

THE AEROPLANE AUGUST 1, 1947

AERONAUTICAL ENGINEERING

Stalling Phenomena and the Tailless Aeroplane—VI

By A. R. Weyl, A.F.R.Ae.S.

Another feature which might even more impede the use of automatic wing-tip slots is the change in chord-wise pressure distribution caused by the upward displacement of the controller flaps, which is required for the attainment of higher incidences. This converts the aerofoils at the tips of a swept back tailless aircraft into heavily reflexed aerofoils under smaller incidence, at which the negative-pressure forces upwards and forwards are not great at the leading edge (Ref. 29). Again, the experience with the D.H.108 has shown that, in spite of this, automatic slots operated satisfactorily.

Northrop has found for his large tailless bomber a solution for fixed built-in slots in the wing tips, by providing shutters (slot doors), which open and close the slot entrance and exit, flush with the wing surface. This should retain laminar flow over the wing tips when flying at high speeds, and also decrease the pressure drag. The operation of these slot-sealing shutters is automatic; they open when the dynamic pressure drops below a specified value and they close when this speed is exceeded.

Seemingly, however, there is little justification for making the slot operation dependent on the speed of flight or a specific value of the lift coefficient, since the phenomenon of stall is solely a function of wing incidence. The Northrop arrangement would thus not be so effective as to exclude tip stall at high speed, say, when flying in a steep turn or while zooming over an obstacle.

It is, of course, purely a matter of design if a smaller profile drag be obtained with wing-tip slots of the Handley Page auto-slot type or with sealable built-in slots. But it: is possible that, for very accentuated angles of sweep (exceeding 50 degrees), the automatic slot may be no more reliable in operation, for the reasons given above. On the other hand, with such angles of sweep and small aspect ratios, the danger of tip stall is not as likely as with medium angles of sweep.

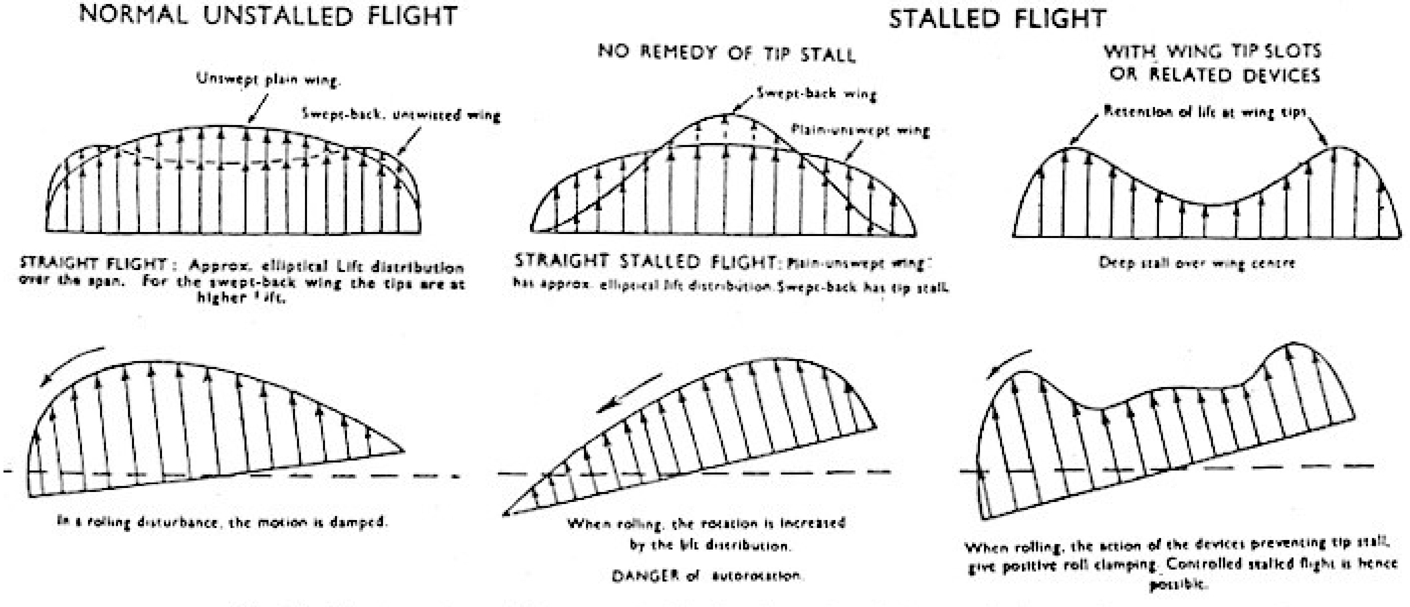


Fig. 11.—The importance of the spanwise lift distribution for flight in stalled attitude.

Wing-tip slots are by no means the only slot device possible to combat tip stall. Slotted flaps might do the same. But they would invariably interfere with the control of tailless aeroplanes. Moreover, they would be inefficient on swept-back wings.

Fair prospects for the prevention of premature tip stall on swept-back wings appear to be given by the provision of nose flaps over the tip region. Leading-edge flaps are in .no way a recent discovery. Originally, they were suggested and employed for control purposes on tailless aeroplanes, and the experimenter first to use them in this way was Réné Arnoux on his first tailless biplane of 1909. Later, the properties of the displacement of hinged parts of the leading edge of monoplane and biplane wings was investigated in this country by the Royal Aircraft Factory and by the National Physical Laboratory in the period between 1912 and 1921.

Variable-camber wings with hinged leading-edge panels were built and flown in this country (e.g., the Saunders Kittiwake), and an American racing monoplane of 1921 (Dayton Wright Gordon-Bennett racer) also employed this feature for speed variation. In 1922 W. L. Le Page suggested then of such leading-edge flaps for the purpose of lateral control. In 1936 C. G. W. Ebbutt suggested nose flaps (as a variation of split flaps at the trailing edge) for the prevention of tip stall, and as a remedy against the abrupt stalling qualities of aerofoil sections with pointed noses.

With respect to tailless aeroplanes, the Horten brothers seem to have experimented early with such nose flaps. In American wind-tunnel research, such flaps were found rather effective in curing the tip stall of swept-back wing systems, and German experiments agree well with these results. In 1945 nose flaps were adopted for the Gotha P.60 tailless jet fighters, to be operated at low speeds and high incidences.

For the development of tailless aeroplanes having substantial sweep, such nose flaps have now become of great interest as organs of stalling stability, as well as control devices. Compared with wing-tip slots, it is assumed, on the basis of wind-tunnel experiments, that nose flaps are twice as effective, judged on equal chord of the device. They are, therefore, considered highly valuable for combating the tip stall at a minimum expense of drag for wing systems of pronounced sweep.

Aerodynamically, such nose flaps are not merely equivalent to a geometrical washout at the wing parts in front of which they operate; their aerodynamic effect is based on a variation of several characteristics. These are: (a) effective incidence; (b) effective camber of the aerofoil section; (c) shifting of the aerofoil-section camber chord-wise; and (d) modification of the nose shape of the aerofoil section (variation of the effective nose radius).

Since nose flaps operate directly at the leading edge, where the boundary layer on a swept-back wing is still quite thin and energetic, their superiority over wing-tip slots is explainable. The modification of the four aerofoil characteristics listed above results in a change in the maximum lift, as well as in the slope of the lift curve, in addition to the unavoidable increase in the profile drag. Moreover, the incidence of zero-lift is varied and causes, together with the decrease of the effective incidence by the flap displacement, the stalling incidence to be reached at the tips only after the critical incidence has been exceeded for the whole wing system. In addition, the adverse pressure gradient in a chord-wise direction is effectively decreased at high incidences over the tip region concerned.

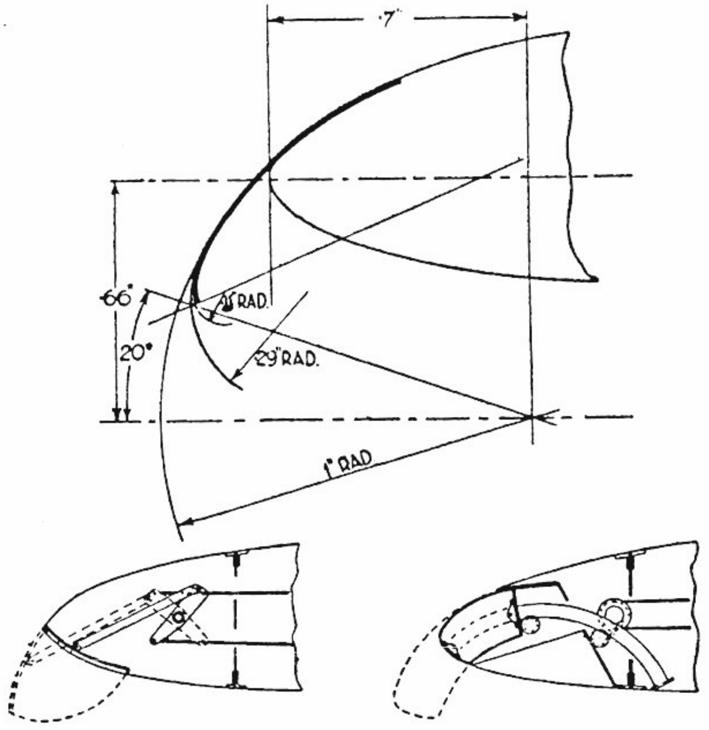


Fig. 12A.—(Above) This nose flap for a wind-tunnel model, proposed by C. G. W. Ebbutt in 1937, gave an increase of 23 per cent. in measured maximum lift coefficient. (Below) Methods of operation of two versions of suggested full-scale Ebbutt nose flaps.

Ebbutt claimed, on the basis of wind-tunnel tests, a maximum-lift increase of 23 percent for his flaps, and also that the additional drag caused by them is less than that of wing-tip slots on unswept wings. Tests of W. Krueger at Göttingen with a nose flap at a 45-degree swept-back tapered aerofoil gave very satisfactory results.

The disadvantage of nose flaps is their operation, which seems to entail high hinge moments for the most efficient varieties; also, the effect of nose flaps on the action of controller flaps located behind them has still to be explored in free-flight experiments.

Of other devices to remedy the tip stall on swept-back wings, the variable-incidence (swivelling) wing tip has already been mentioned in connection with the wing twist. Diffuser wing tips could be expected to utilize the span-wise flow components for an acceleration of the boundary layer away from the wing tips in a backward direction. They may thus be less affected by the disabilities connected with abrupt changes in the distribution of the effective incidence along the span.

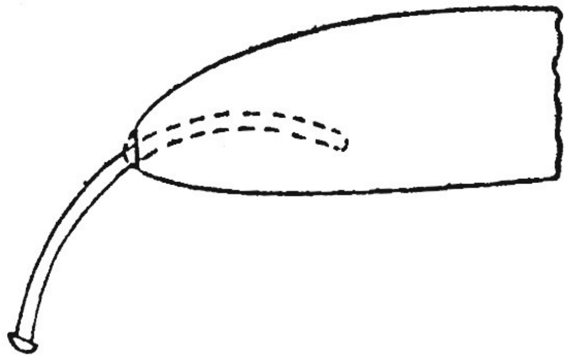


Fig. 12B.—A German example of a nose flap for tailless aeroplanes.

Attempts have been made to restrain the span-wise flow in the boundary layer along the upper-wing surface of a swept-back wing. The provision of inboard fins near the tips would seem to be effective for this. Soldenhoff seems to have been the first to apply this device, and on one Gotha tailless fighter-bomber similar provisions seem to have been made near the trailing edge. On the whole, however, this remedy does not appear to be nearly as efficient as other devices; moreover, it greatly adds to the drag. The drag increase is much felt at high speed, when the restriction of span-wise flow is not at all necessary.

A rather poor method occasionally adopted for tapered wings is that of provoking premature stall at the wing-root at an incidence below that at which the tip stall would occur. It implies a direct loss of maximum lift and has nothing to recommend it for the design of tailless aeroplanes. Generally the application of fixed spoilers, sharp leading edges or equivalent concoctions conducive to premature root stall seems evidence that the designer learned from the test pilot that aircraft suffered from tip stall.

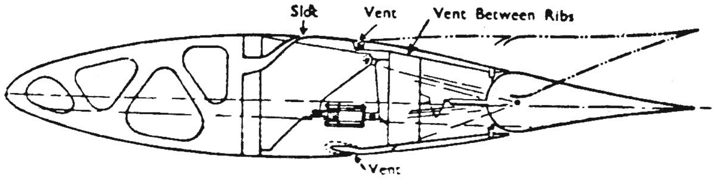
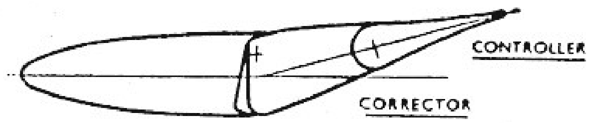


Fig. 13.—Boundary layer suction as applied to the Armstrong Whitworth A.W.52G experimental glider.

Better prospects for a remedy of the tip stall is offered by the control of the boundary layer by means of artificially introduced pressure differences. The application of boundary layer removal from regions near the tips has often been suggested; it was first tried in flight on the Armstrong Whitworth A.W.52G tailless glider. With this, a single slot (with interruptions by the wing ribs) was provided on the upper wing surface at about 44 percent chord. The slot extended over the tip region occupied by the two-purpose controller and was in front of the trimmer surface, to which the controller flap is hinged. The width of .the slot, the shape of which is shown in Fig. 13, decreased towards the tip, so that the flow quantity taken in was greatest at the inboard end.



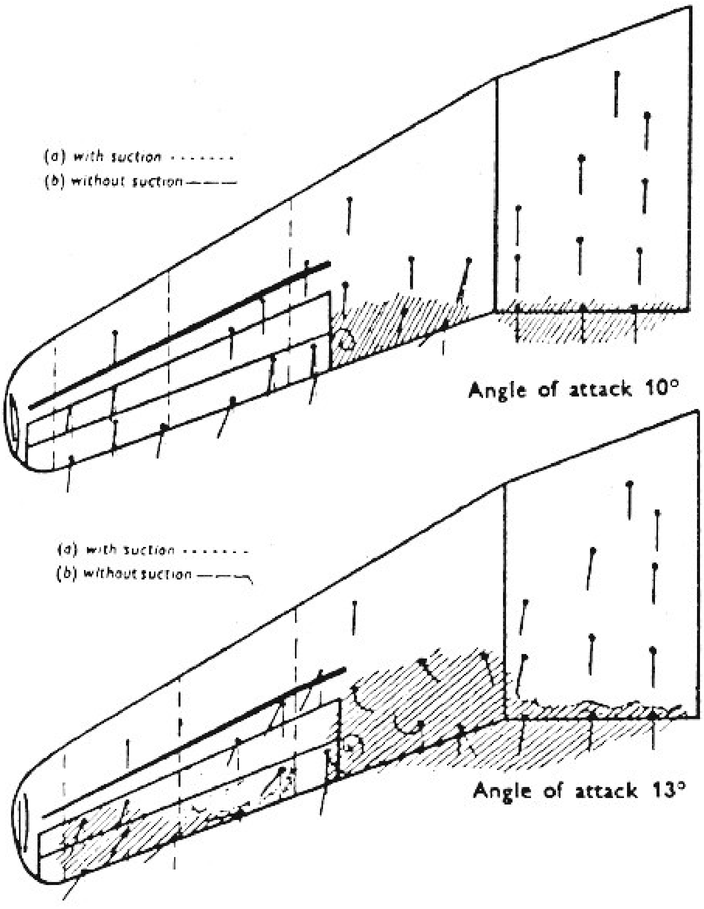


Fig. 14.—The effect of boundary layer suction on the Armstrong Whitworth A.W.52G glider at two incidences. The position of the streamers indicates the effect. Regions subject to stall without removal of the boundary layer are hatched.

On the glider, suction was supplied by two windmill-driven blowers, which were attached to the undercarriage legs. On the jet-propelled flying wing the compressor of the turbo- jets can take air in through the slot. During the tests with the experimental glider and in wind-tunnel tests this suction method has given satisfactory results. The wing to which it was applied was of the laminar-flow type with sections having a theoretical transition point at 40 percent chord.

Boundary-layer removal by suction on wings with sweep-back is by no means as effective as it is on unswept wings. The reason is that the boundary layer on the swept wing is rather thick in the region of the tips and at the incidence at which the removal is wanted for prevention of premature tip stall. Consequently, a considerable quantity of flow material will have to be removed in order to make the method effective.

From theoretical estimates it would appear that, for effectiveness, between 75 percent and 100 percent of the "displacement thickness" of the boundary layer (i.e., one-fourth to one-third of its entire thickness) will have to be removed. Possibly, experimental evidence will enable this considerable quantity to be reduced, but up to now tests have not given much hope in this direction for tailless aeroplanes. Regenscheit and Schwier, for instance, found at Göttingen that suction on wings with pronounced sweep-back had but little effect on the tip stall. In any case, it is obvious that the plain removal of the boundary layer by sucking it away from the tips is rather inefficient, i.e., expensive in power, while its effectiveness for larger angles of sweep is still in doubt.

As to the inefficiency, it may, however, be reasoned that the suction method does not necessarily require additional machinery, or even power, to function. With gas turbines or turbo-jets, the suction may well be obtained from the intake side of the compressor or by way of injector arrangements from the expelled gases of the jet or exhaust. Moreover, the suction is only required at transient conditions of flight and for short periods, such as for take-off, climb, glide and landing. It is even conceivable that, from the aspect of overall economy of the aeroplane, boundary-layer removal will not mean expense of power at all when the sucked-in air is utilized for specific purposes (e.g., for cooling).

On the Armstrong Whitworth glider the provision of wing-tip discs—usually promoters of premature tip stall—actually seemed beneficial in combination with the boundary-layer removal. The reason for this is that they prevent excessive flow around the wing tip, from the lower to the upper wing surface, when the suction operates.

Boundary-layer removal by suction will, unfortunately, not guarantee complete stability in stalled flight. While longitudinal stability can be secured for an unswept wing, boundary-layer suction may cause, on a stalled wing, acute lateral dynamic instability. Stueper observed in stalled-flight tests with a suction flap (Ref. 82) that the rolling moment derivative to rolling (1p) may, with suction, give rolling oscillations of increasing amplitude when flight in a stalled condition is maintained. The reason is that when one wing droops, due to the suction, the lift at this wing is more than restored, at the expense of the lift at the other wing.

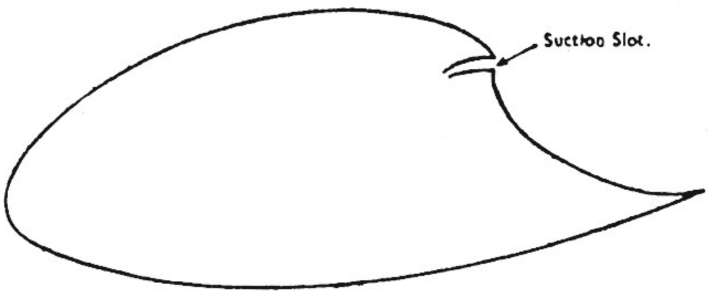


Fig. 15 —Shape of a very thick suction aerofoil of the Griffiths type: the thickness ratio is 38 per cent. of the chord. The aerofoil has a stationary centre of pressure and a maximum lift coefficient of 2.5.

On tailless aeroplanes with swept-back wings and suction at the tips only, the dynamic longitudinal stability also would most probably be affected to some extent. A remedy may be found in automatic regulating devices, adjusting the air intake to the lift requirements and preventing more air from being removed from one wing-tip than from the other. Considering the unstable flow pattern during and after development of the stall, wing dropping is unavoidable at the stall (due to temporary loss of lift) with or without suction: This implies a pressure increase on the suction side of the dropping wing and the removal of more air from this wing tip, while the up-going wing has initially more lift and less air sucked away. A motion similar to a Dutch Roll may follow for a tailless aeroplane.

As distinct from this simple method of removal of the boundary layer from the tip region, G. H. Lee (Ref. 84) investigated the adoption of laminar-flow suction-aerofoils of the Griffiths or Lighthill type to swept-back tailless aeroplanes.

Superficially, the difference would seem to be only one of quantity, yet effects and results are greatly varied. The plain removal of the boundary layer from an aerofoil is able to delay the separation of the flow up to very high incidences, and hence a very high maximum lift can be obtained. The intensity of the suction applied has to increase with the incidence.

The laminar-flow suction aerofoils developed in this country should retain a laminar state in the boundary layer over a major part of their chord in order to reduce the frictional drag of the aerofoil. Hence, a very much smaller intensity of suction is required. One peculiarity of such "stepped" section profiles (Ref. 85) is that the chord wise pressure (or velocity) distribution varies from that of ordinary aerofoils, in that the adverse pressure gradient on the upper surface towards the trailing edge is reduced. The adoption of such sections for the tip regions of a swept-back aerofoil should thus have the twofold effect of reducing the intensity of the outward flow over the wing (because of reduced span-wise pressure gradients at equal chord stations), and of a reduced tendency to flow-separation at the tips (because of the decreased pressure gradient towards the trailing edge).

There is, therefore, the possibility of achieving a substantial improvement for far smaller expenditure in suction. The suction may be applied at the aft step of the suction aerofoil. Lee suggested double suction profiles with an additional air intake at the pointed leading edge. Though this may promise a further improvement in the chord-wise velocity distribution, the suction at the leading edge can easily cause a loss of lift due to adverse effect on the circulation if not properly adjusted. There are reasons to believe that this is difficult to arrange for all angles of incidence. As a result, the lift does not remain a linear function of incidence and the stability qualities vary for different conditions of flight.

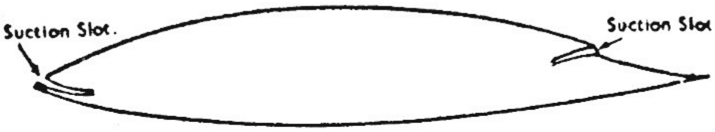


Fig. 16.—Shape of a suction aerofoil of the Lighthill type with two suction slots.

Another advantage arising from the adoption of suction-profiles is that very thick sections may be used without disadvantage from the point of view of profile drag. This is not only structurally desirable and vital for flying wings, but also promises very gentle "rear"-stall qualities, even in the case of suction failure. Moreover, these thick suction-profiles give high maximum lift coefficients, though at greater expense in suction power.

When suction-aerofoils of the Griffiths or Lighthill type are adopted for the entire wing system of a tailless aeroplane, the premature tip stall would not be entirely eliminated with substantial degrees of sweep-back. As a remedy, G. N. Lee (Ref. 84) suggested the application of more suction at the wing-tip region than over the central parts of the span.

Since the outward flow over the upper surface of a swept-back wing is most noticeable near the trailing edge, while over the nose of the wing inward flow exists in the boundary layer, E. J. Richards has recently made an interesting suggestion for the improvement of the stalling qualities of swept-back wings (Ref. 80). The gradual rear stall (form "C") should be seriously affected by the boundary flow of the swept-back wing—which is not evident from the collected N.A.C.A. results. Most of all, sweep back should actually delay the gentle laminar front stall (form "A"). Richards therefore suggests tests with very thin wing-tips, because it is to be expected that for these, sweep-back will eliminate their tendency to the stall-form "A" and convert it to the turbulent rear stall of the form "C". The local flow along the nose would emphasize the small curvature of the leading edge.

The discharge of air from slots located near the leading edge on swept-back aerofoils has hitherto been investigated in wind tunnels only, and the results indicate a better effect than plain suction. In spite of this, the tests of Regenscheit and Schwier at Göttingen have not given results, which can be considered satisfactory for tailless aeroplanes with substantial sweep-back.

There is, however, the possibility that a combined system of suction and discharge may remedy the premature tip stall in an effective and efficient way. Systematic experimental research in this direction is required. Since with identical arrangements control could be affected without incidence-linked control-surface deflection, the author has recommended the adoption of pressure-controlled suction-discharge wing-tips for flying wings at an early date.

Another way to remedy the tip stall is to decrease the outward flow in the boundary layer by decreasing the angle of sweep towards the tips. This was a feature of the Henschel tailless (by F. Nikolaus) and model tests proved promising. The modification of the plan-shape by reduction of the sweep would undoubtedly be effective, but will result in structural problems. It is not recommended for aeroplanes operating near the range of impending compressibility stall.

THE AEROPLANE AUGUST 15, 1947

AERONAUTICAL ENGINEERING

Stalling Phenomena and the Tailless Aeroplane—VII

By A. R. Weyl, A.F.R.Ae.S.

Only relatively few experiments have been made with tailless aeroplanes employing sweep-forward. Yet the swept-forward wing possesses one advantage over swept-back or tapered wing systems: there is no premature tip stall, and during the incipient stall, neither the roll damping nor the effect of control flaps at the wing tips is lost. On the swept forward wing (Buzzard category) the stall sets in at the wing root and spreads from there to the tips, if no wing twist or other devices modify the lift distribution over the span.

The reason for this phenomenon is similar to that responsible for the tip stall of the swept-back wing. A span-wise flow component in the boundary layer induced by the sweep of the leading-edge, carries stale boundary-layer material across the upper wing surface towards the wing root, while the boundary layer over the wing tips is continuously renewed. At the root, the thick, de-energized, flow material accumulates owing to the contribution from both wings at that point. This boundary layer easily separates from the wing surface when an incidence is reached at, which an adverse chord-wise pressure gradient brings it to stagnation and back-flow.

The premature stall at the wing root will result, however, in a decrease of the longitudinal stability as well as in a tail-heavy trim at the stall as in the case of the plain swept-back wing. In this respect, the difference between the two systems of sweep is one of quantity only, not of quality. Further, since with forward-swept wing systems the elevator is best located near the wing root, the control in pitch suffers when the incipient stall occurs.

Irving found (Ref. 6) that sweep-forward greatly reduces the rolling moment due to side-slip (l_v), and that for this the rake of the trailing-edge was mainly responsible, by reason of the inward flow component. Consequently, the swept-forward-wing would require, for equal lateral stability, more dihedral than an equivalent straight wing. With a flap at the wing root, the demand for dihedral would be even more accentuated.

Probably the first to make general use of sweep-forward, seems to have been Dane Hulburt, whose -second monoplane flew in Switzerland in 1911 with such a wing system. Sailplanes (such as the Kirchner "La Pruvo" with swivelling wing tips, 1927) and light aeroplanes (Klemperer, 1923, for instance) have occasionally been designed with a slight sweep-forward. This was done either to obtain an improved field of vision, or in the hope of securing a higher maximum lift, or to achieve aileron control beyond the stall. In more recent times the Swiss Pilatus SB-2 safety monoplane deserves mention because of its exploitation of the properties of swept-forward wings. The Junkers firm has also made an experiment in that direction.

For tailless aeroplanes, sweep-forward has been employed hitherto only in a few highly experimental designs which were either scarcely tested or not tested at all (Landwerlin Cerreur, 1922; Cornelius, 1942). Apart from these only some model experiments have become known.

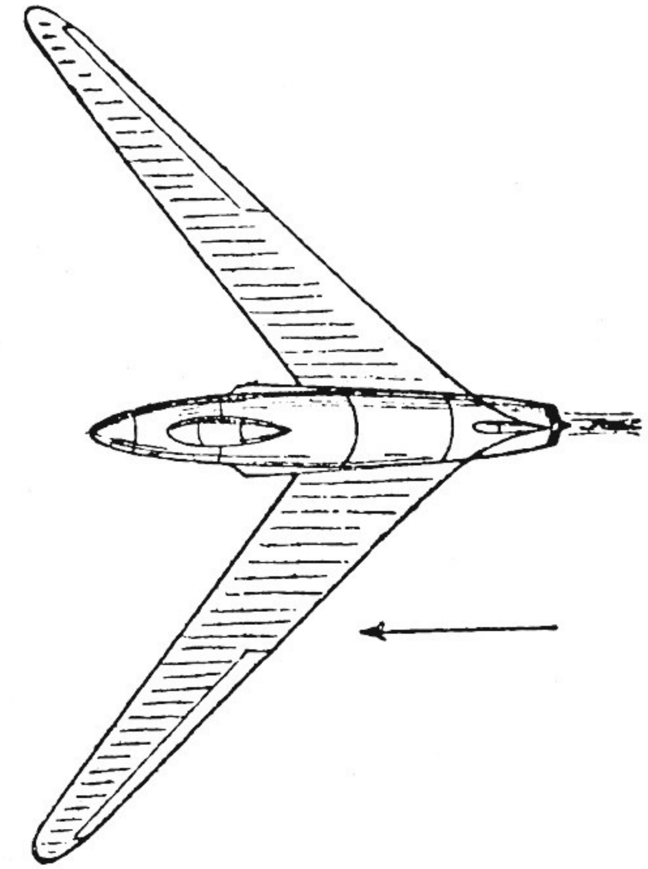


Fig. 17.—Suggested design for a swept-forward tailless single-seater for very high flying speeds. The arrow indicates the direction of flight.

Low-aspect Ratio Wings

When discussing the properties of sweep-back, the American tests of suitable combinations between sweep and aspect ratio were mentioned. Research in Germany during the War, especially by Lippisch, which was mainly based on the results obtained by C. H. Zimmermann of the N.A.C.A., also clearly indicated that satisfactory slow flying and stalling properties could be obtained with large angles of sweep when very small aspect ratios were adopted. In order to arrive at a clearer understanding of this problem, it is advisable to consider the properties of low-aspect ratio wings separately from swept wings.

An early discovery of experimental aerodynamics was that aerofoils having aspect ratios of the order of unity (for instance, wings of circular or squared plan shape) exhibit lift maxima, which are higher than that of wings of normal proportions. Eiffel observed such "lift" properties on flat plates in 1909. Later investigations confirmed that up to 20 percent increase in the maximum lift could be gained in that way, at incidences that were higher than the critical incidences of ordinary wings. In other words, the slope of the lift curve decreased at such low aspect ratios, in addition to the greater maximum lift.

The delayed stall of such small aspect ratio aerofoils attracted the interest of F. Handley Page (now Sir Frederick Handley Page) when he embarked on a search for high-lift wings with safe stalling qualities (a search which led him finally to the slotted wing). In a 1911 paper, he expressively commented on it, pointing out that a square aerofoil stalled at an incidence of 40 degrees, while an aerofoil of identical section but an aspect ratio of 6.25 had a critical incidence of only 10 to 15 degrees (Ref. 18). Later, Handley Page tried to convert a rectangular wing into square elements by the expedient of span-wise slots, in order to obtain high stalling angles. This first step towards the slotted wing, however, proved disappointing (Ref. 19).

In the meantime, the Lanchester-Prandtl theory had come to dominate aeronautical engineering, and designers became so conscious of the induced drag that low-aspect ratio wings were ignored. L. Prandtl himself found in 1920 (Ref. 20) that the theory of induced drag based on the simple "horse-shoe" vortex-line hypothesis, did not agree with his experimental results when aspect ratios of 2 and less were investigated. The induced drag found experimentally for such aspect ratios was noticeably smaller than the calculated one, and the slopes of the lift curves ($d\,C_L/d\,\alpha$)also differed greatly. Prandtl pointed out that the simple vortex-line hypothesis was responsible; he suggested that, in theory, such low-aspect ratio aerofoils ("Disk" wings) should be treated as staggered multiplane systems. But even then, the results of corresponding calculations remained quantitatively unsatisfactory, due to the assumption of an elliptic lift grading.

In about 1932, the N.A.C.A. began to investigate the properties of Disk-type wings. For experimental research in this direction, C. H. Zimmermann became mainly responsible. As main representative of this trend of development, he has since become the designer of the Chance-Vought experimental helicopter-aeroplane, with low-aspect ratio wings.

Zimmermann soon found that rounding of the wing tips exerted a profound influence upon the aerodynamic properties of such wings. He therefore included circular aerofoils in his research (Ref. 21). Somewhat later, swept-back tailless aeroplanes of aspect ratios of the order of 3 were investigated by F. E. Weick and R. Sanders (Ref. 22). This investigation has obviously influenced the research work of A. Lippisch.

Circular aerofoils (Aspect Ratio=1.27) gave 50 percent more maximum lift than an aerofoil with an aspect ratio of 6 having the same aerofoil section. This more than confirmed the results Eiffel had obtained with his primitive facilities for aerodynamical experimentation. The lift-curve slope was greatly decreased. This indicated improved flying qualities for the circular-disk wing, with the stall delayed to exceptionally high incidences (otherwise found only on slotted wings) and with greatly diminished sensitivity against gusts.

TAILLES TOW – This view of the General Aircraft tailless research glider clearly shows the elevons, here acting as elevators. The hook like protuberance under each fin is a skid to protect the fin in the event of a "wing tip" landing.

For somewhat higher aspect ratios, on the order of 3, it was found that the peak of the lift curve was rounded, so that either no range or only a small range of possible autorotation (spinning) could be expected. Contrary to this, for aspect ratios smaller than about 3, Zimmermann's tests established that at the stall the peak of the lift curve became sharp as well as discontinuous, although the critical incidences were high (between 35 and 45 degrees). There are indications that no gradual stall can be expected on such disk-type wings, although there are no investigations yet known which cover the scale effect. On the other hand, there are indications that such low aspect ratios combined with pronounced sweep-back at the leading edge give well-rounded peaks in the lift curves (Ref. 76).

On the whole, the flow on a disk-type wing is dominated by the induced drag that is by the flow caused through pressure equalization over the tips (Ref. 23). The negative pressure on the dorsal surface near the trailing edge of the tip increases with the incidence and exerts a great effect on any controllers located in that region. This may be the reason why Zimmermann's Chance-Vought designs have the controllers as separate additions to the wing tips, abandoning the true tailless conception.

At small incidences, the pressure distribution over the wingspan will correspond approximately to that of a conventional wing. Dihedral on disk-type wings seems to decrease the drag, but does not decrease the diving moment experienced at incidences approaching the stall. Slots had little effect on the qualities of these wings.

On such wings, a pronounced span-wise flow component *inward* along the upper wing surface is a characteristic of the predominance of the induced drag. For sweepback, it was an *outward* flow component, which was responsible for the premature tip stall and for the tail-heavy pitching moment arising there from at the incipient stall. Hence the idea of combining the two features in order to arrive at satisfactory stalling qualities is well founded and, as the experimental results indicate, entirely practicable.

The High-incidence Stall and the Path of Flight

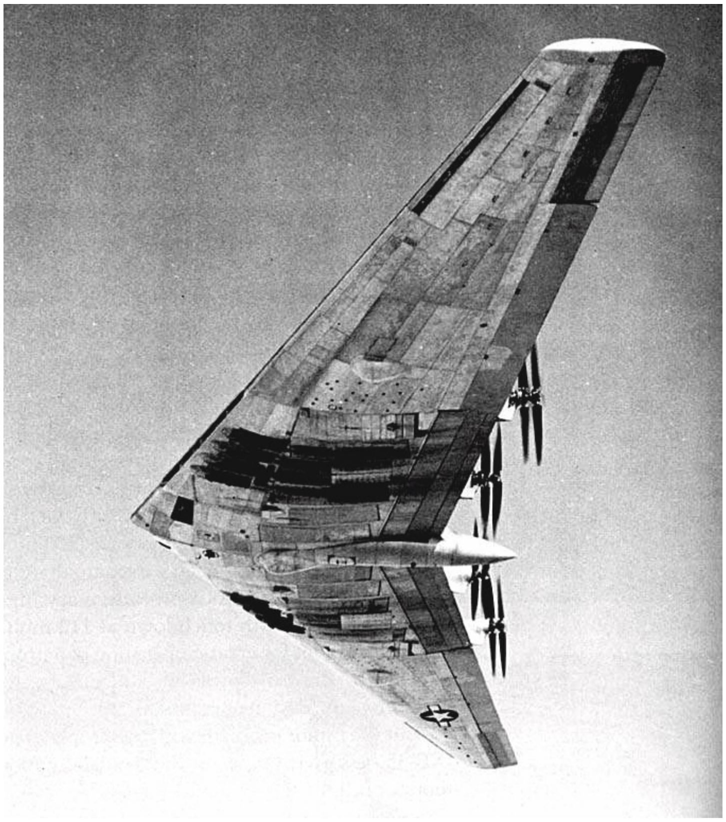
Good behavior during a straight stall is by no means conclusive proof that the stalling qualities are innocuous. Yet the behavior of an aeroplane during and after a straight slow stall is to a certain extent indicative of the absence of primary deficiencies at the incipient stall or, alternatively, of the necessity of taking corrective measures.

Also, the presence of longitudinal stability in pitch during the incipient stall is by no means a proof that the stalling qualities are satisfactory, but is, however, a condition which prevents inadvertent stalling.

Commonly, five forms of behavior during a straight gradual stall are easily distinguished, provided that the elevator power is sufficient to exceed the incidence of maximum lift—a critical condition for the majority of all tailless aeroplanes. These forms are:

A. Nose-heaviness with a tendency to decrease the incidence; in severe cases, the aeroplane simply dives away.

B. Stick-force reversal to tail-heaviness, combined with sinking on an even keel.
C. Yawing combined with side-slip, under slow dropping of a wing; the resulting motion is either that of a tightening spiral or of a "Dutch Roll."
D. Violent longitudinal oscillatory instability within a limited incidence range, beyond which the conditions become more normal.
E. Abrupt wing dropping without yaw; violent instability combined with complete loss of control. Transition to autorotative motion (spinning).



FLYING AGAIN – After reduction gear troubles in the Wasp Major power plants, flight trials of the Northrop XB-35 all wing bomber are now being resumed at the Muroc Army Air Base, California. Later versions of the aircraft will use eight straight jets.

The form "A" would seem indicative of lack of elevator power as well as of the presence of stability in pitch. A more powerful elevator would be required before an opinion on the stalling qualities could be pronounced.

Form "B" suffers from instability in pitch, but otherwise indicates the possibility that the stalling qualities may be satisfactory.

Form "C" can be presumed common for tailless aeroplanes with pronounced sweep-back, and possibly for swept-forward types also.

Form "D" with an incidence range of fluctuating lift has been observed with swept-back tailless aeroplanes of moderate sweep. Installed glides with the Hill Pterodactyl Mk. 1, a distinct region of instability was observed at which the maintenance of a steady flight-path was found impossible. The same phenomenon was observed on the Westland-Hill Pterodactyl Mk. IV. To quote from an unpublished report of G. T. R. Hill: ". . . It was found impossible to fly steadily at full throttle over an incidence range several degrees beyond the stall. If stalled with engine-on and the stick pulled back, the incidence rapidly increased to about 30 degrees, with little change in the attitude of the aircraft to the horizon. The pilot did not notice the rapid transition without instruments."

That such a region of flow-instability is not a characteristic of tailless aeroplanes as such, has been proved by the result of exacting stalling tests with the He.280 twin-jet fighter. Here too a critical region beyond the stall was established which could be passed through by quick stalling.

The stall form "E" should be avoided under all circumstances, and aerodynamically there appears to be no reason for tailless aeroplanes to be more afflicted with it than conventional aeroplanes. Moreover, there is no experimental evidence for the occurrence of this stall form on swept-back tailless aeroplanes.

Stalling during circling flight might seriously modify the characteristics of the stall. The Horten brothers claimed to have experienced very abrupt stalling with incipient spinning under this condition.

Apparently tailless aeroplanes and gliders are prone to convey to pilots wrong impressions as to their stalling qualities. With them, the probability of loss of control in pitch rather early during a gradual approach to the stall is high. The subsequent impression gained of an innocuous stall should not be allowed to stay. The stalling qualities may still be quite unsatisfactory, and this may appear quite accidentally when the aircraft is stalled during circling flight or by an up-gust. The readiness to flow separation is an inherent quality of the wing system and not connected with the elevator power, as some promoters of "safety" aeroplanes prefer people to think.

The tailless aircraft has for many years been regarded by some aeronautical engineers as the layout of the future. Much work has already been accomplished in this direction but a great deal more still remains to be done. The advent of really high-speed flight will no doubt accelerate such development.

(ed. The References section of this paper will be published in the next issue.)

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