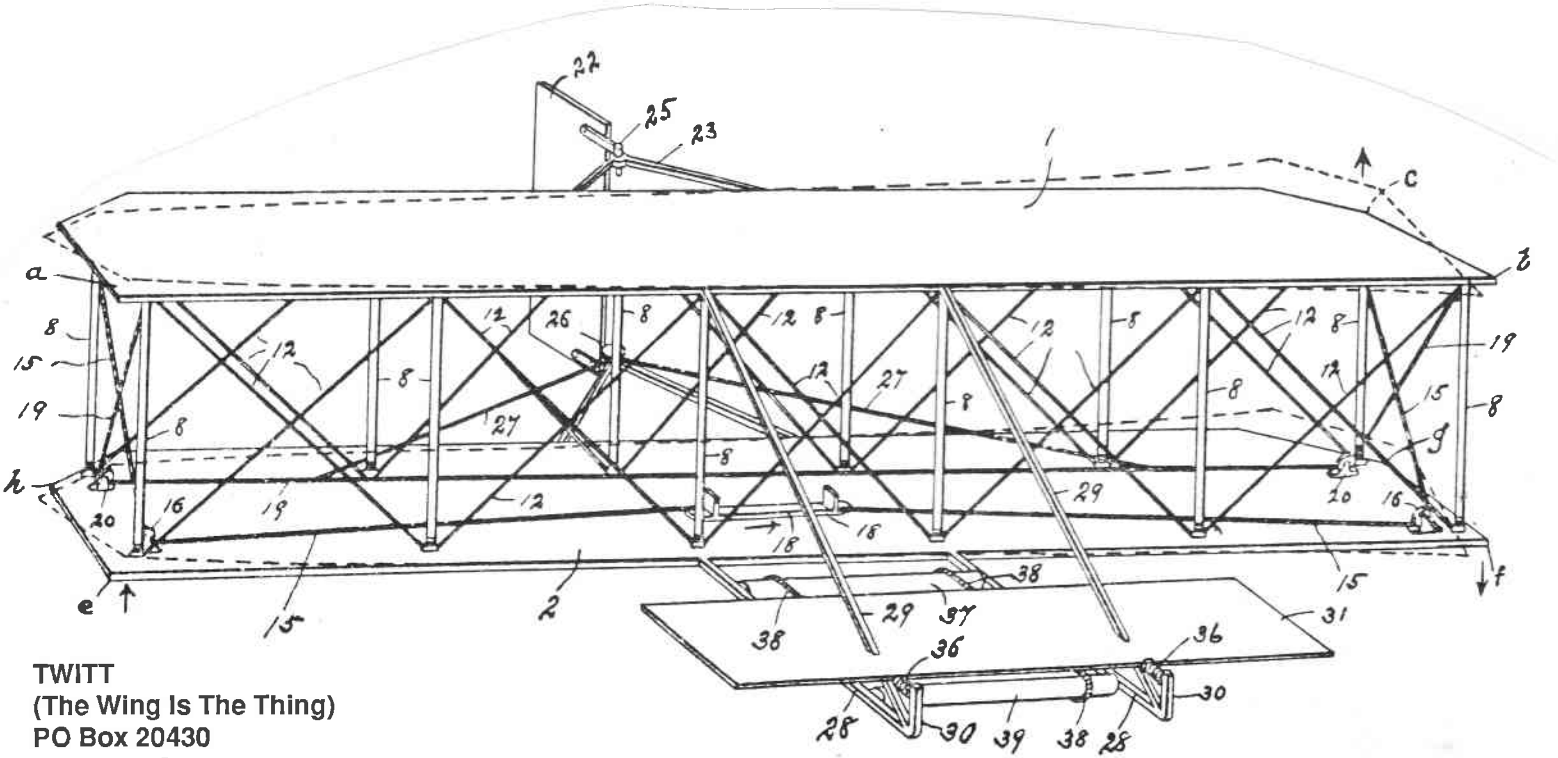
NUMBER 30 DECEMBER 1988

TWITT NEWSLETTER

F. Marc de Piolenc, Editor and Publisher



TWITT
(The Wing Is The Thing)
PO Box 20430
El Cajon, CA 92021
USA

The numbers in the upper right corner of your label indicate the last issue of your current subscription, e.g. 8812 means this is your last issue.

NEXT TWITT MEETING: Saturday, 17 December 1988, beginning at 1330 hours. As always, the location is Hangar A-4, Gillespie Field, El Cajon, California, in the first row of hangars on Joe Crosson Drive.

CONTENTS

MINUTES OF TWITT MEETING, 19 NOVEMBER 1988

Present were: Bob Fronius, June Wiberg, Fortunato "Tuto" Figueroa, E. J. Kremzier, Ladislao Pazmany, Andy Kecskes, Jorge Paullada, Bill McCaffrey, Marshall Randall, Doug Fronius, Todd Hodges (NASA-Langley), Reg Finch, Stephen Opgenorth, Ed Lockhart, Jerry Blumenthal, Klaus Savier, David Barnard, Bruce Carmichael, John Chalmers, Paul Hanson, Barbara Boyle, Greg Kendall, Billy Grey, Ralph Wilcox, Carol {?}, and Phil Fulton. After Bob Fronius called the meeting to order, he asked visitors to introduce themselves. Bruce Carmichael presented Todd Hodges from NASA-Langley; Todd works with advanced composite materials and offered to answer questions from TWITTs on that topic. Dave Barnard from Poway, California introduced himself as a pilot who is interested in building himself an airplane. Bob Fronius then took the floor to make some announcements. The Edwards Air Force Base Open House was a great success. The TWITT raffle less so; it was taking in less money than it put out. Bob also mentioned the Great Configuration Debate at the Aerospace Museum on December 9, which will oppose advocates of conventional (Penaud style) and unconventional (flying wing and multi-surface) airplanes. There will be TWITTs and TWITT speakers on both panels. Bob noted that tailless airplanes are not really unconventional, and that in San Diego they have been common. He mentioned among others the Convair F-92, "century series" fighters, the Sea Dart and Waldo Waterman's (certified) Arrowbile. He then introduced Maurice Brockington, developer of the BEC aircraft conversion of the Mazda 13B twin-rotor Wankel engine. Maurice had brought with him a preliminary design for a fast 4-place airplane designed around one of his engines [a sketch was published in NL 29—Ed.]. A panel, consisting of Hernan Posnansky, "Tuto" Figueroa, Phil Burgers and Doug Fronius met to provide constructive criticisms of the design. Your Editor heard the discussion on audio tape and was therefore unable to see blackboard drawings, blueprints and so on so much of the discussion was obscure. One key points were that if Maurice intended to certify the airplane, some provision needed to be made for certifying it first with a conventional certified aircraft engine, and for certifying the BEC engine on a certified test bed airplane; Doug Fronius felt it would be very difficult, if not impossible, to certify an engine and airplane simultaneously. Another point made was that the wing loading was marginal as designed, leaving no room for the inevitable weight "growth" of new airplane designs. The consensus was that simple full-span flaperons, coupled with a span extension, was superior to the idea of engineering a sophisticated high-lift system. Asked why he showed the radiator mounted above his engine, Maurice pointed out that Steve Wittman has had a light airplane flying successfully for years with a radiator installed over a converted Oldsmobile V-8. On the subject of sheared wingtips, someone in the audience (Todd Hodges?) mentioned that some difficulty was being felt in verifying theoretical performance improvements in the wind tunnel; there was improvement, but not as great as expected. Another comment (Todd Hodges again?) concerned the relative positions of the minimum pressure stations on the wing and fuselage. It turns out that if they coincide, drag is noticeably increased because of boundary layer separation. Offsetting them helps. This insight appears in a DFVLR yearbook [Probably means DVL; DFVLR was its name after WW II—Ed.] from the late Thirties!

DECEMBER MEETING PROGRAM

December 17 is the 85th anniversary of the first controlled, powered flight of a heavier-than-air aircraft at Kitty Hawk, North Carolina. TWITT is fortunate in having its regular meeting date fall on the 17th. Our speaker will be Bill Chana, who is an authority on the Wright brothers and an aviation legend in his own right. After Bill's talk we will show the 40 minute videotape "How Strong is the Wind" about the Wrights' experiments. The TWITT raffle prizes will be two posters entitled "First in Flight," each with its own Certificate of Authenticity. Each paid-up TWITT Newsletter subscriber will receive a copy of the original Wright patent drawings and document. We will have a piece of the original material that covered the Wright Flyer at Kitty Hawk on its first flight. This has been lent to TWITT by a San Diego area resident who knew the Wrights and called them "Uncle."

B-2 ROLLOUT

Your editor watched the B-2 rollout ceremony on closed circuit television from a restaurant called the Proud Bird, near Los Angeles International Airport. The "media event" was arranged by the Aviation Writers Association (AWA) in cooperation with Northrop. We actually had better seats than the people sitting in the bleachers at Palmdale, the cameras zooming in for close- ups of the cockpit canopy and the air intakes. Camera angles, however, were restricted; no rear views of the airplane were shown, and the undersurface of the wing was also not visible. A low-camera-angle still picture appeared on the cover of a national news magazine, so it is possible that the TV shots were limited to the upper surface for reasons other than security. Everything about the rollout was different from other, similar events: speeches were short, relevant and well delivered and the presence (and obvious pride) of the Northrop employees at the site lent the proceedings a festive atmosphere.

After the presentation of the machine itself, Secretary of the Air Force Baldridge held an informal news conference in which he astounded me by showing a very thorough understanding of the machine squatting threateningly behind him and a cheerful lack of tolerance for frivolous and irrelevant questions. At the Proud Bird Bill Schoneberger, who had organized the "do," introduced various notables, the only one of any interest to me being Max Stanley, an original Northrop test pilot who flew the XB-35, YB- 49 and YRB-49A. Mr. Stanley was easily recognizable from 30 year old photos, proving that in addition to their other virtues, flying wings keep a fellow young. After Bill's introductions and before everybody attacked the buffet lunch, a series of small press conferences organized themselves around the luminaries whom Bill had thus thrown to the wolves. As I approached Max Stanley, hoping to recruit him as a TWITT speaker, I saw a female radio reporter thrust a microphone in his face and ask him what "all this Stealth stuff" was really about. He answered politely, but I didn't think an organization called "TWITT" would get much of a hearing after that whopper; Mr. Stanley had surely had all the twitts he could stomach for one day.

As to the airplane itself, your Editor has had to eat his words, having confidently asserted that the trailing edge had been heavily retouched in the Air Force artists' drawings released to the Press. It was clear from the shadow of the machine on the concrete that the trailing edge sawtooth shape is exactly as advertised. The leading edge is perfectly straight, coming to a point at the nose, again just as shown. There is an optical illusion caused by the sharp change in taper that makes the machine look kinked from in front; again the shadow of the l.e. settled the question. In one of the closeups of the air intakes, I saw what I interpreted to be a boundary layer suction slot just inside the scoop opening. The scoops themselves are farther forward than I expected, nearly at the leading edge. There was some talk at the table of the Air Force "doctoring" the intakes, but I don't see the point. In hindsight, it is obvious that a 'plane that will be flown by day will eventually be photographed in all its particulars, so changing the scoops with *papier-mâché* for the rollout seems infantile. I saw no evidence of control surfaces on the wing trailing edge. Since that time, Aviation Week has come out with vertical aerial shots clearly showing control surfaces.

The technical press has made a great deal of the influence of radar cross-section considerations on design, implying more than once that only those constraints could justify an "unstable" configuration. Interestingly, the presentation speeches mentioned increased range, low fuel consumption and ability to penetrate enemy air defenses at either high or low altitude at will. The very *last* virtue mentioned was Stealth! The B-2 has the approximate span and l.e. sweep of the XB-49 of nearly forty years ago, a belated but welcome endorsement of Jack Northrop's design formula. It's too bad he did not live to see the culmination of his work. We were told, however, that shorly before his death Northrop was given a special briefing on the Stealth bomber project, then in its infancy. If this is true, then he at least knew that his conception of the Flying Wing would eventually return to the American sky.

SWALC

(Swept Wing Automatic Lift Control)

Flying Wing Automatic Camber Flap Mechanism with Landing Assistance

by

Hansjoerg Ackermann
Schwalbenstrasse 5
4133 Neukirchen-Vluyn
FEDERAL REPUBLIC OF GERMANY
Tel. 02845/5031

First draft 15 December 1983; revised 2 July 1986

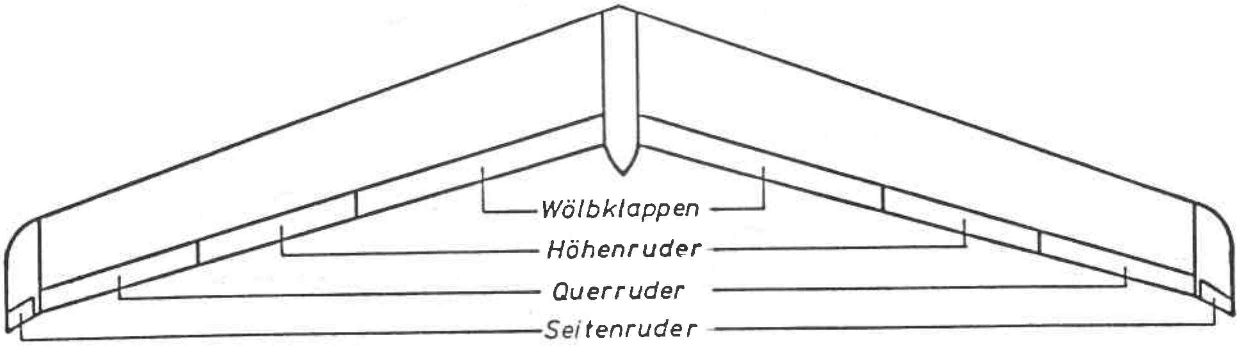
The automatic mechanism causes opposite overlapping operation of the aileron/elevator system and the inboard camber flaps. The wing trailing edge is divided into 6 control surfaces, the inner surfaces acting as camber flaps. The intermediate

SWALC

(swept wing automatic lift control)

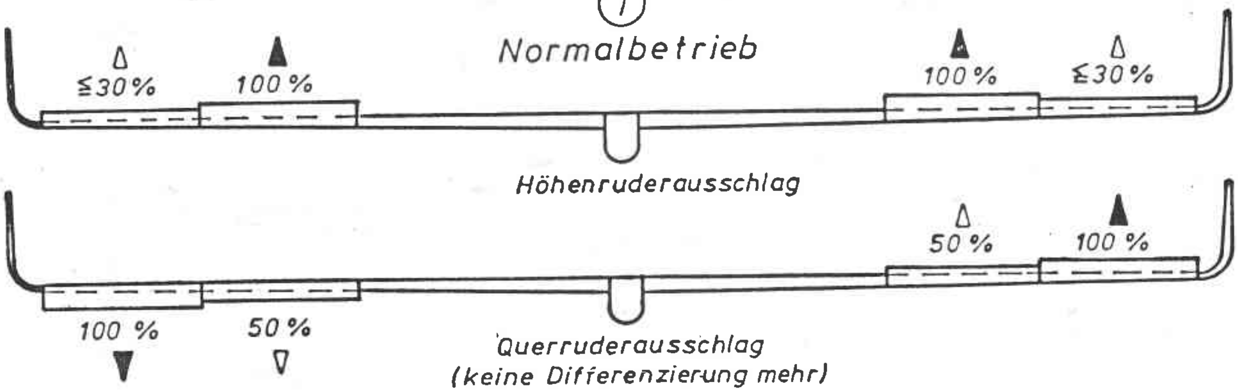
Nurflügel-Wölbklappen-Automatik

mit Landehilfe



①

Normalbetrieb



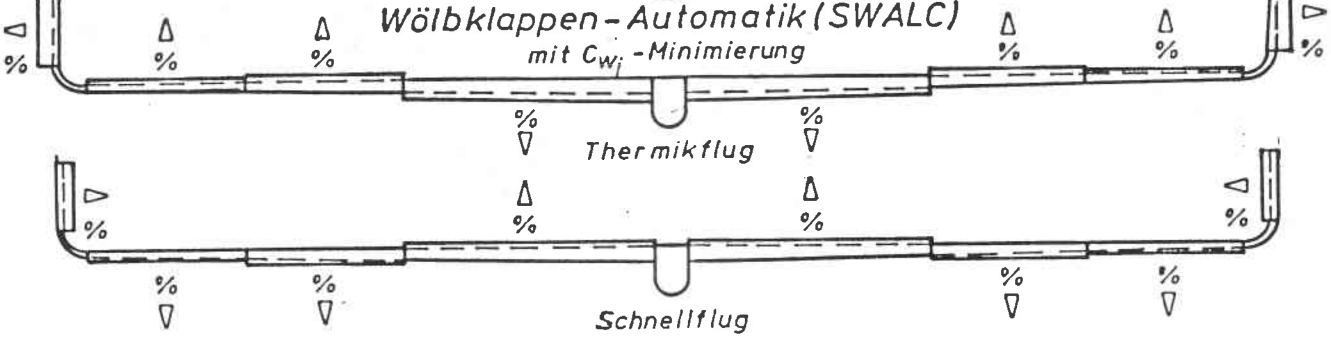
Höhenruderausschlag

Querruderausschlag
(keine Differenzierung mehr)

②

Wölbklappen-Automatik (SWALC)

mit C_{W_i}-Minimierung

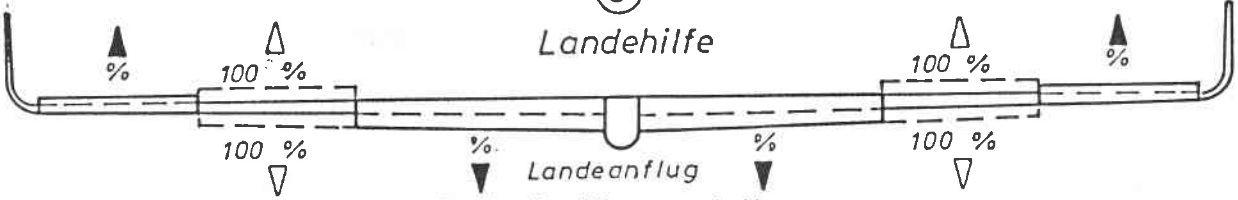


Thermikflug

Schnellflug

③

Landehilfe



Landeanflug

Butterfly-Klappenstellung

% ≙ individuell

surfaces operate mainly as elevators, the outer surfaces primarily as ailerons.

① **Normal Operation**

The intermediate elevators deflect with the outboard ailerons through a controllable differential so that the ailerons move only slightly when elevator control is used, keeping the wing washout substantially constant and preventing large trim changes. When aileron control is used, the elevators deflect with the ailerons through a controllable differential linkage which causes the elevators to deflect less, maintaining a smoother wing twist.

② **Automatic Camber Flap Mechanism (SWALC)**

Normal operation is supplemented in that the inboard camber flaps are coupled with the elevators through a variable differential. The camber flaps and the elevator/aileron system deflect in opposite sense. The optimum flying wing washout is thus automatically matched to the current airspeed. In order to minimize induced drag, the winglet-mounted rudders are deflected outward through a variable differential when up elevator is selected, and inward for high speed flight when down elevator is used, thus optimally matching winglet angle of attack through changes in chord line deflection to flight angle of attack. The variable differential rudder function, present in any case, is maintained in full. The aileron or rudder function can be selected for priority.

③ **Landing Assistance**

The ailerons cooperate with the camber flaps through a manually controllable differential link so that large deflections produce a wing with high washout and excess stability about the lateral axis, allowing steep descents and short landings to be carried out. In this mode, the intermediate elevators do not deflect with the ailerons and the ailerons do not follow elevator deflections. The elevators remain fully controllable for glide path selection.

Translated by F. Marc de Piolenc

LETTERS

Peter C. King of Roswell, Georgia, a new subscriber, writes:

Do you have a list of topics in the back issues?

Your Editor, shamefaced, replies:

Not yet. We definitely need one, though; the problem is time. If there are any TWITTs out there interested in compiling an index of Newsletter back issues, we'd like to hear from you. Before you leap to reply, note that we have a special problem, in that much of the useful information we convey appears in our Letters column, which will be especially difficult to index. Most publications skirt this problem by ignoring it and simply not indexing letters.

NEED INFO ON PLANS, KITS

Harold D. Buck of Columbus, Georgia, another new subscriber, writes:

I have been a soaring pilot for many years and currently fly a Nimbus 3/24.5 and a Mini Nimbus but am interested in perhaps building a flying wing. I would like to know if there are any plans or kits available that your group would recommend. If there is any way in which I might help your group please advise me. Thanks and good luck!

Major G.M. Hostage III of Burke, Virginia writes:

I would like to know of some flying wing designs available to the homebuilder. I am familiar with the Backstrom "Plank" and Mr. Marske's Pioneer IID. I have a set of plans for the IID and have about decided to build one. Before I do, I want to make sure I have not missed out on any other possibilities.

Your best sources of information on tailless sailplanes (other than TWITT, of course) are:

Soaring Society of America
PO Box E
Hobbs, NM 88240

Sailplane Homebuilders' Association
490 Broad Avenue
Leonia, NJ 07605

The only tailless sailplane kit that we know anything about is the Marske Pioneer II. Some issues back, we covered Bernie Gross' Pioneer, Deaf Hawk. There must surely be other kits, and we know of plans for at least one Horten machine now in the care of the SHA. One of these days we need to compile a list of all the plans and kits that TWITTs know about. As for recommendations, I'm sure you will understand our reluctance to recommend anything without knowing the kit or the builder directly. Please let us know how your research turns out.

WINGS FROM THE EAST?

Dave Laney writes:

I had talked over the phone to Gil Metcalf [who provided info on the Schapel SA-882 flying wing to TWITT—Ed.] who told me of your organization and dues. I was most pleased to hear of your organization and am studying Horten, Lippisch and Northrop designs. I am a pilot and have over 18,000 hours accumulated here as well as New Guinea, (Irian Barat) Indonesia and Africa. My specialty was STOL/bush operations.

I would love to fly a wing! Perhaps there would be a market for a light 2 place powered wing offering an excellent L/D—built with composites and manufactured in the Far East where I lived. I found a lot of aircraft talent, skilled hands and rock bottom labor costs over there.

It's a thought. The availability of cheap, efficient light aircraft would be a boon to the US buyer and a source of economic growth for the producing countries. Unfortunately, the biggest single cost component for US–produced aircraft (and now kits, too) is the cost of insuring against frivolous and malicious tort suits. A foreign producer would be shielded to some extent, though his US distributors and agents would not be. Still, the low labor costs might (assuming a reliable source of materials) give the offshore producer such an advantage in US markets that the hoped–for recovery of the US light aircraft industry would never take place. Obviously, if it comes to a choice between flying a foreign product and not flying at all, the choice is obvious. But it is clear—at least to me—that if this country is to avoid decaying to the status of a third–rate agricultural state, we need to rebuild our system of education and our domestic industry, giving aerospace top priority. As long as there is any hope at all for that program, the idea of offshore production of aircraft—be they ever so humble—doesn't do much for me.

FARRAR FLYING WING—1950

Charles Pearson of Birmingham, Alabama writes:

A check for $15 is enclosed to cover 12 issues of your news letter on tailless aircraft. I am most interested. In 1950 I helped Franklin Farrar take his flying wing to the nationals in Grand Prairie, Texas. Thanks for performing this service.

June Wiberg, Original TWITT, recalls the following: "Wally Wiberg had told Farrar that if he would get the wing to the 1950 Nationals, he—Wally—would test fly it. Farrar brought it, Wally got into it after looking it over, and played with the controls. They were all mixed up, and the workmanship was so poor on the entire wing that he refused to fly it—the only thing I knew him to refuse to fly. Wally flew an LK that year in the Nationals and placed 5th."
Does anyone out there have 3-views or photos of Farrar's machine?

TWITT IS ON PROBATION!

Syd Hall of Nevada City, California informs us:

Dear Mr. Fronius:

The issue of TWITT which you sent did not impress me, but [Al] Backstrom said you had covered some items that I'd better check up on. Therefore $21.00 for 28 back issues...and I hope my evaluation will improve to the extent that I subscribe.

Sincerely,

Syd Hall

We'll let all of you know the results of Mr. Hall's evaluation, so you can govern yourselves accordingly.

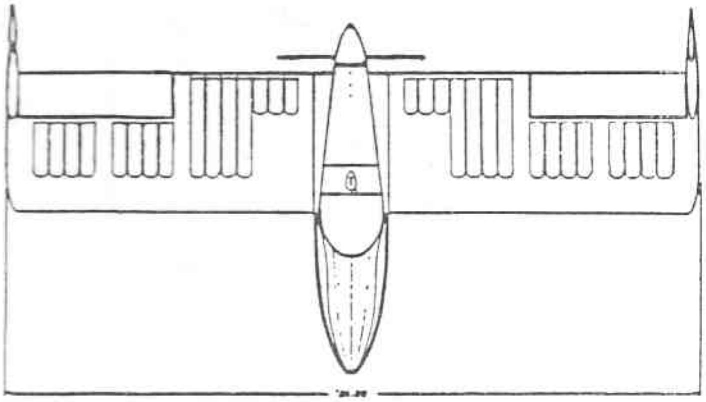
BUILDING FAUVEL AV222

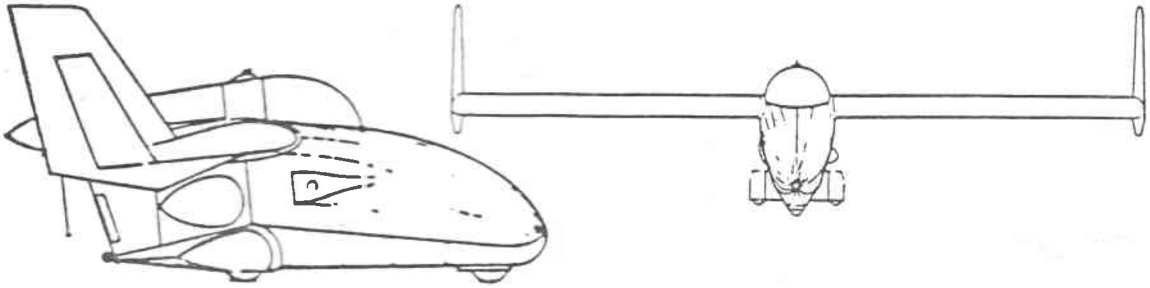
Kenneth Weyand (another new subscriber—hurrah!) of Anchorage, Alaska writes:

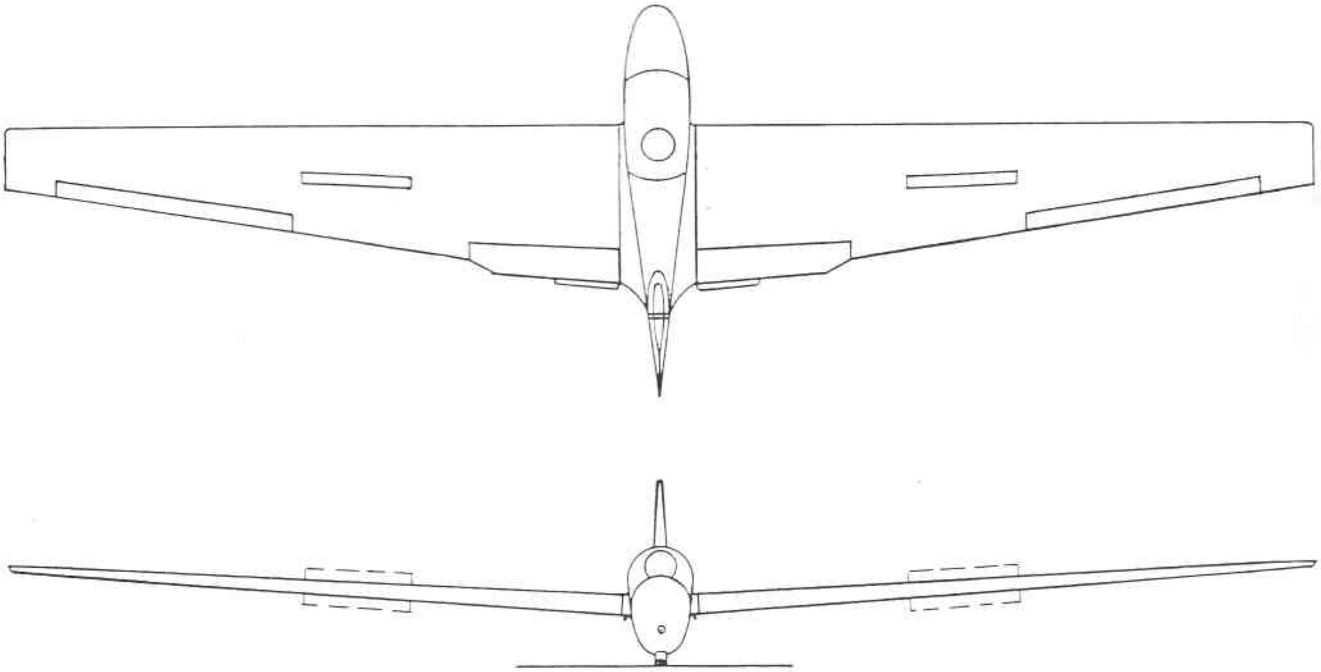
I am presently constructing a Fauvel AV-222 motor glider and am interested in your organization.

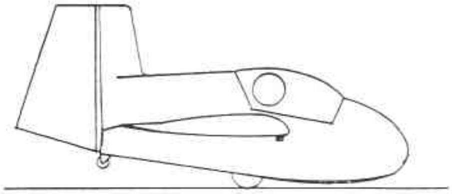
We are interested in your progress. Please let us know how your project turns out.

3-Views Courtesy of
EAA "Sport Aviation"
February 1980 Issue
Drawing by Dick Johnson









PIONEER II

SPAN	42 FT.
AREA	147 SQ. FT.
ASPECT RATIO	12
AIRFOIL	23112-75/23110-75
FUSELAGE LENGTH	12.5 FT.
EMPTY WEIGHT	370 LBS.
FLYING WEIGHT	600 LBS.
WING LOADING	4.1 PSF

Stalling Phenomena and the Tailless Aeroplane—V

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

Previous instalments of this article appeared [redacted] in NL 20, 23

THE N.A.C.A. tests, discussed in the previous instalment, were made with an NACA 23012 aerofoil section on the following plan shapes:—

Angle of effective sweep.	Aspect ratio.
60 degrees	2.52
45 ,,	3.56
30 ,,	4.36
0 ,,	5.0

The wing span and the wing width (normal to the leading edge) were in all cases the same. The Reynolds Number of the tests was between 1.0 and 2.0 × 10^6.

The stalling behaviour is characterized by the shape of the pitching-moment wing-incidence curve. The influence of the stall development on swept wings is very informative. But in basing design considerations on these qualitative results, it ought not to be overlooked that the effect of the change in aspect ratio is as well marked as that of sweep.

For the unswept wing with an aspect ratio of 5, the pitching-moment curve is straight, up to the incipient stall. After this point it turns steeply towards negative (nose-heavy) pitching moments, and a tendency to decrease the incidence (i.e., stability) is experienced. For the wing with 30 degrees of sweep-back, however, the curve turns up when the stall develops. Even a substantial amount of wash-out does not constitute a complete cure.

An experimental tailless research glider of General Aircraft, Ltd., had 28.4 degrees effective sweep-back, RAF.34 aerofoil, an aspect ratio of 5.8 and 5 degrees wash-out. During flight tests with this aircraft it was found that, when made to stall, the nose rose a few degrees (i.e., proof of instability), but then dropped again when the stall spread along the span.

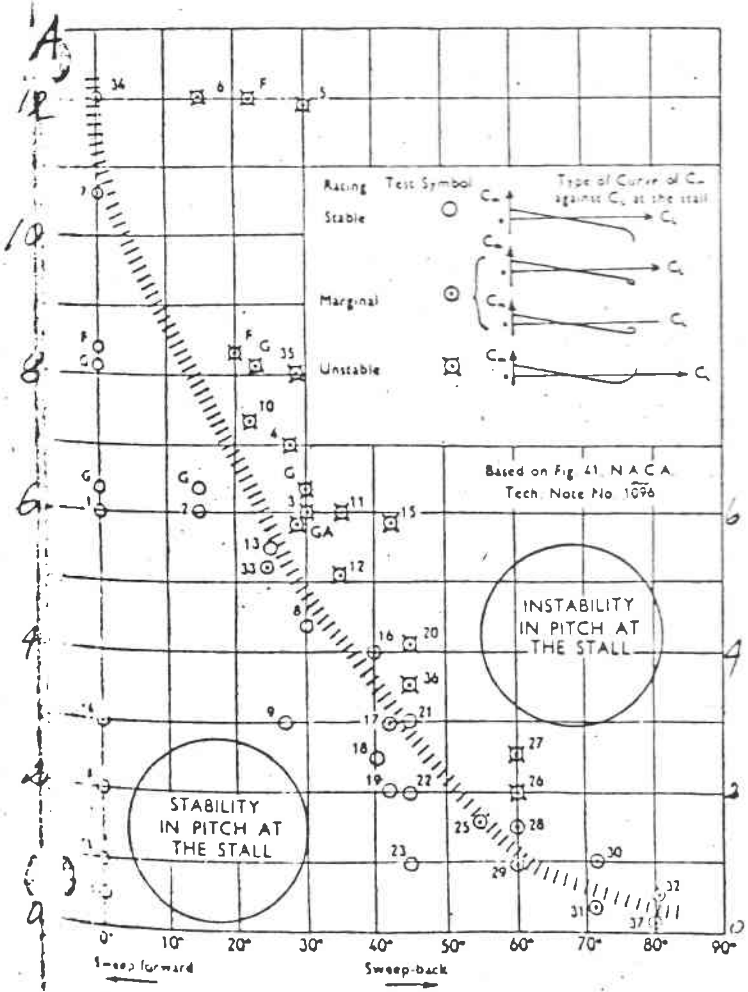


Fig. 8.—Longitudinal stability of swept-back, untwisted wing systems at the stall, as a function of sweep and aspect ratio

F. Anderson, of the N.A.C.A., found in earlier wind-tunnel tests (Ref. 77) that 30 degrees sweep with an aspect ratio of 6, a taper ratio of 2 and 8.5 degrees wash-out, proved unstable at the stall, while a wing system having 15 degrees sweep gave stability at the stall without any wash-out.

For larger angles of sweep, and consequently lower aspect ratios, the somewhat surprising phenomenon was observed that a negative slope of the pitching-moment curve appeared at incidences well below the stall. This unexpected increase of the longitudinal stability occurred at sweep angles of 60 degrees or more, even at incidences which correspond to those of high-speed flight.

Although this phenomenon has nothing directly to do with what is commonly understood as a stall, not only is it characteristic for the combination of sweep and aspect ratio investigated, but, in addition, may well constitute a certain measure of danger. The pronounced increase in the static longitudinal stability (due to the backwards shift of the aerodynamic centre) means not only a sudden appearance of nose-heavy trim, but also a reduction in the effectiveness of the elevator control ("frozen control" at high speed). Soulé has also pointed out that the phenomenon may be responsible for the diving tendency when flying at speeds near to that corresponding to the critical Mach Number of the aircraft; this is, however, not quite true.

At higher incidences the shape of the pitching-moment curve for the wing of pronounced sweep again shows the tendency to increase the incidence. Obviously, the instability at the stall arising from the change in the slope of the pitching-moment curve is connected with the effective sweep as well as with the aspect ratio. The sweep, however, seems to be the main factor, judging from other tests than the N.A.C.A. tests, when the sweep alone was varied (e.g., Ref. 71). But from the comparative N.A.C.A. investigations it is established that the higher the aspect ratio (i.e., the slimmer the wing plan), the smaller becomes the angle of sweep-back at which instability at the stall becomes apparent.

The comparison made by Shortal and Maggin (Ref. 76) proves (for aerofoils without twist or any other devices curing the wing-tip stall) that with a sweep-back of 15 degrees and an aspect ratio of 6, the wing system is stable at the stall, while with the same sweep but an aspect ratio of 12, instability in pitch at the stall becomes apparent. This reflects badly on the properties of tailless sailplanes like those of the Horten brothers, which consequently require an undue amount of twist in order that the stall shall become innocuous.

On the other hand, a wing system with 30 degrees sweep and an aspect ratio of 6 was unstable, while with an aspect ratio of 4.36, the same angle of sweep-back resulted in a stable pitching-moment curve. The American results tally well, both qualitatively and quantitatively, with earlier German experiments at Goettingen and with the results found by Ferrari at Turin on the Piana-Canova tailless development (Ref. 78).

Seemingly, the combination of sweep-back and aspect ratio forms the major factor for the shape of the pitching-moment curve at the stall. Since the "stick-free" stability at the stall is important for the safety and the flying qualities of tailless aeroplanes, the designer will have to take this into account.

Soulé and his collaborators at the N.A.C.A. have condensed their experimental results in a helpful diagram, which relates to aerofoils without any wing twist. The boundary indicated in this diagram should, however, be accepted with care. Only the influence of sweep and of aspect ratio have been taken into account. The choice of the aerofoil section will also be important, to an extent which is hitherto still unexplored. Moreover, however important the stick-free stability at the stall is, it does by no means reflect completely the nature and qualities of the path of flight and the attitude of the aeroplane when the incipient stall takes place.

So, for instance, there might be a nose-heavy (stable) tendency at the incipient stall. The corresponding slope in the pitching-moment curve may, however, be so abrupt and severe that the aeroplane tends to dive away suddenly without the possibility of control, rendering a quick [illegible] "safety" aeroplanes, and has given rise to a large number of severe accidents. The stall, too, may spread so suddenly span-wise and chord-wise that it becomes relatively unimportant for the pilot whether the feel of the stick is nose- or tail-heavy; the question of control effectiveness is of paramount importance at that instant. Hence, the N.A.C.A. diagram will form a useful guide for the designer, but it should not be deemed conclusive for a final decision on the wing plan.

The taper ratio (root chord/tip chord), too, has an effect on trim and stability at the stall. Its increase, i.e., a pronounced taper, aggravates the occurrence of the premature tip stall at equal effective angles of sweep. The reasons are the same as those valid for the unswept tapered wing. Hence, taper promotes stick-free instability at the stall.

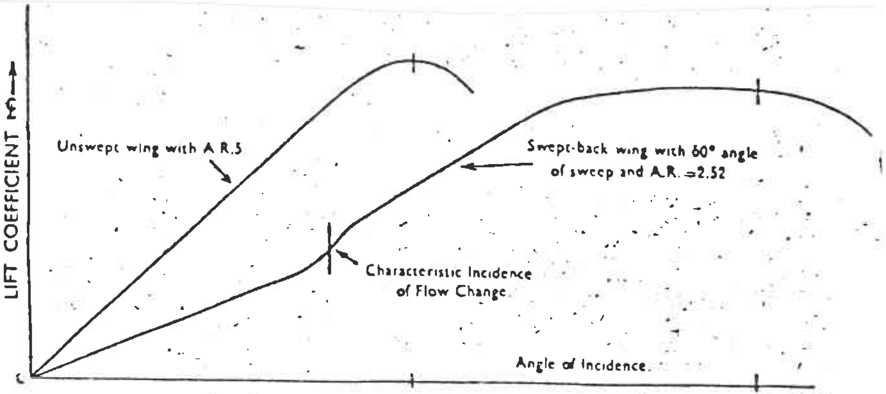


Fig. 9.—Lift curve for an unswept wing and for a swept-back low aspect-ratio wing of equal aerofoil section (N.A.C.A) [from N.A.C.A. Tech. Note No. 1088]. The variation in $\frac{dC_L}{d\alpha}$ at the characteristic incidence is worth noting.

For low-aspect ratios, however, taper may have just the opposite effect. In free-flight tunnel experiments of the N.A.C.A., wing systems having 42 degrees sweep-back and aspect ratios between 2 and 3, a taper ratio of 1.4 gave erratic stability at the stall, while pointed wings indicated clear stability at the stall, though with curvature of the pitching-moment curve at sub-critical incidences.

The presence of a fuselage does not seem to exert a great influence on the characteristics of the pitching-moment-curve slope at the stall.

There is reason to presume that, when the aspect ratio is too large for a given sweep-back, unstable pitching moments will occur during and after the incipient stall. If the aspect ratio is too small, the aerodynamic centre will shift at all speeds of flight and, at the stall, the longitudinal stability will be so excessive as to impair seriously the controllability. The reason for this is the influence of the tip vortices on the flow over the wing; with decreasing aspect ratio this influence increases, but taper seems to reduce it.

The slope of the lift curve ($dC_L/d\alpha$) generally decreases with decrease of the aspect ratio. But wing combinations of the kind investigated by the N.A.C.A. (as, for instance, sweep of 45 degrees combined with an aspect ratio of 3.56, or sweep of 60 degrees combined with an aspect ratio of 2.52) exhibit distinct kinks in their lift curves, with noticeable increases of the lift-curve slope at higher incidences beyond a "characteristic" incidence.

This is an indication that a change in the state of flow in the boundary layer is taking place at this "characteristic" incidence. Indeed, in the N.A.C.A. tests an observation of silk tufts showed that the flow change at the "characteristic" incidence was accompanied by a slight ruffling of the tufts near the leading edge in a region at about 40 per cent. of the semi-span from the root. The provision of a small barrier to span-wise flow at this region (mid-span fin disc) exerted an appreciable effect, both on the lift-curve slope and on the pitching-moment slope (both with respect to the wing incidence). This observation may have some bearing on the flow mechanics, causing unorthodox behaviour over the certain laminar-flow aerofoils mentioned earlier.

fence

The flow change also exerts an influence on the static directional ("weathercock") stability ($dN/d\beta$) and on the rolling moment, due to side-slip ($dL/d\beta$) of the wing. Both stability derivatives (of which the former is critical for the design of "flying wings") assume reversals in their moment/incidence curves for some wing incidences, quite distinct from the influence of tip stall.

Apart from the peculiarities in longitudinal stability at the stall, sweep-back is also prone to give trouble in lateral stability at higher incidences of flight. At high incidences, sweep-back has the same effect on the lateral motions as dihedral, and pronounced sweep gives the characteristics of excessive dihedral. The consequences are unstable or badly damped lateral oscillations. This is very noticeable at incidences near the stall, and the flying qualities at take-off and landing may be badly affected by it. How far the aspect ratio has an influence does not yet seem to be experimentally established, but may be presumed as present. The resulting motion arising from the deficient lateral oscillatory instability may easily take the form of "Dutch Roll," i.e., a non-damped yawing and rolling motion due to the excessive dihedral effect. This effect is not remedied by devices intended to avert the premature tip stall, but is directly connected with the sweep-back.

The experience that sweep-back can lead to lateral instability at high incidences is actually a very old one, but apparently forgotten. Nearly 35 years ago pilots and designers became well aware of it. Probably Dunne experienced the trouble before anybody else, but there is no conclusive evidence of it. Bomhard in Vienna, who originated the swept-back Lohner reduced it on subsequent models to only 12 degrees because too much sweep-back was found to cause lateral oscillatory instability during take-off and landing. The adoption of staggered biplane arrangements and of pronounced wash-out, which was finally adopted for the Lohner biplanes, according to a 1911 patent of Bomhard, did not prove a remedy (Ref. 83). From Austria, the swept-back biplane fashion spread to Germany, and there again designers began with angles of sweep of 30 degrees and more (L.F.G., Union-Bomhard, etc.). The same results were found and the angles of sweep were subsequently reduced on all these biplanes.

Parallel with this, Fokker had identical experience with his first monoplanes. Though the angle of sweep-back was only about 9.5 degrees, the addition of a dihedral of 9 degrees rendered the Fokker "Spider" troublesome and vicious during take-off and landing. The effect was so much felt that the Prussian military authorities refused to accept the design for this very reason. Thirteen years later Fokker returned with the D.XIV fighter with his original features combining an effective sweep-back of 14 degrees with 7 degrees dihedral. The design was not satisfactory, though the fatal crash experienced with it was most probably due to premature tip stall leading to a flat spin.

In more recent times, "Dutch Roll" instability had been predicted by R.A.E. tests for the de Havilland D.H.108 experimental tailless aircraft for incidences below the actual stall. In practice the disturbance seems to have been observed, but has not proved troublesome.

The Remedies of the High-incidence Tip Stall

The stalling phenomena discussed can be varied by devices to remedy the premature flow-separation in the region of the wing-tips. Devices which have been found practicable for this purpose can be divided into two categories. They are either those by which the increase of the section lift at the tips (which follows from the sweep-back) is directly reduced, or those which delay the stall at the wing-tip and make it occur at higher effective incidences.

To the first kind belongs the remedy of wing twist, i.e., a washing-out of the effective incidence towards the tips. This changes the lift grading over the span (i.e., the section lifts) at all incidences.

Consider a stable swept-back wing system with tips so twisted that their local incidences are essentially smaller than that of the wing at the root. Such a wing will obviously reach the critical incidence first at a region of the span, inboard of the tips. Obviously, when such a twisted wing system approaches the stall it will provide "stick-free" stability, i.e., a tendency to decrease the incidence, because the lift contribution of the tips will then give a nose-heavy trim. Such "wash-out," moreover, is coincident with the fundamental condition for static longitudinal stability at all incidences of normal flight.

This coincidence is, however, only a qualitative one. Actually, for the achievement of static stability in pitch for normal positions of the centre of gravity, less wing-twist is required than for the prevention of tip stall. Both requisites depend upon the amount of sweep for their magnitude, but only the former is directly related to the centre-of-gravity location.

Even a very substantial amount of wash-out is not sufficient to exclude the occurrence of premature tip stall entirely. A considerable degree of wing twist may easily be neutralized by a rolling motion, with the result that one wing-tip stalls before the other one.

In any case, wing twist is not very desirable; it is wasteful in drag. Not only does it increase the profile drag, but by modifying the lift grading from that of an elliptical one the induced drag, too, is increased. Wing twist reduces the critical Mach number and is presumed bad for the compressibility-stall alone is not sufficient to prevent tip stall, even in straight flight.

Thus, obviously the device of wash-out has only limited scope and will remain restricted for small angles of sweep-back only. When wash-out is employed as a device against premature tip stall, two considerations should be borne in mind. One is that, however pronounced the twist may be, it will not form an absolute safeguard for the reason stated. To consider the incidence-change induced by a rolling motion would lead to abnormal and quite uneconomical wing twists. The Dunne biplane had 45 degrees wing twist between the "bustle" and the tip.

Secondly, twist is best distributed along the span. If the wing is shaped with wash-out over the tips only, the adjoining regions of the span will have large differences in pressures and lift; consequently, high span-wise pressure gradients will be formed. The result is that premature separation will be induced at such regions of different lifts; these are likely to upset the beneficial influence of the wash-out. The least penalties are erratic stability qualities.

The same consideration also applies to tips with variable incidence. As soon as regions with different section lifts occur at neighbouring strips of the span, the pressure gradient becomes easily large enough to promote a premature separation of the flow. This restricts the range of utilization for variable-incidence wing tips. Flow separation has actually been observed immediately inboard of wing-tip controllers.

Although even somewhat more limited in scope, the increase of section camber towards the tips, which the author introduced as a remedy against premature tip stall on tapered wings in 1936 (Ref. 28), is more efficient against premature tip stall. Flight tests at the R.A.E. have since proved that the increase in section camber slows up the break-away of the airflow. In addition, the loss in lift sustained beyond the critical incidence is less catastrophic, and this would allow the retention of some measure of control at the stall. Of all the simple remedies for tip stall, this seems still the best; its influence on the induced drag is smaller than that caused by geometric twist and the increase in profile drag, due to span-wise pressure gradients, can be made exceedingly small. M. A. Garbell (Ref. 79) has recently given a method of aerofoil selection for highly tapered and swept-back wings based on the device of highly cambered wing-tip sections. The effectiveness of this has been experimentally proved for taper ratios of 4 and angles of sweep-back at the leading edge of up to 15 degrees.

For tailless aeroplanes with moderate sweep-back, a combination of twist with increased section camber towards the tips would, hence, seem to have prospects. For larger angles of sweep, however, none of these simple devices appears as a practicable method of effecting a cure.

Among the stall-delaying devices belong the wing-tip slot and the provision of leading-edge flaps near the wing tips. Slots delay the stall, for the span region covered by them, up to very high incidences. Since they retain the same value of the lift-curve slope over the extended range of incidence, their use results in a higher maximum lift. However, considering the maximum lift of the entire wing system, the effect of wing-tip slots is but small and, on swept-back wings, marred by the effect of the sweep. Slots—even those of the full-span variety—give a small increase in the maximum lift if span-wise flow components, arising from sweep-back of the leading edge, are present.

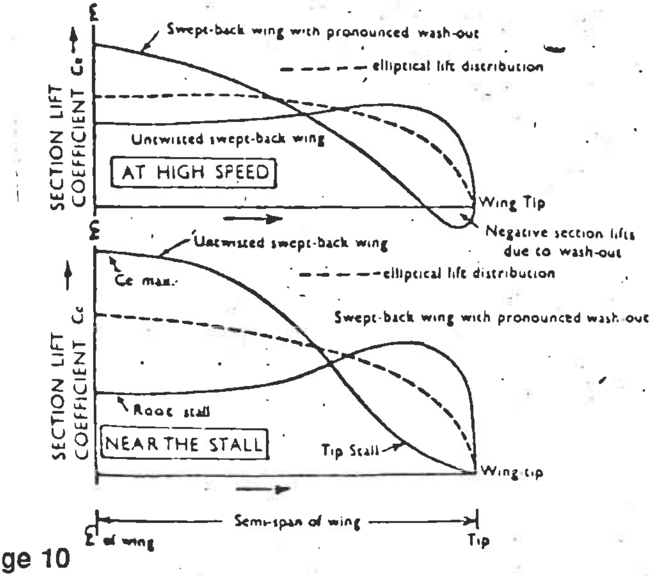


Fig. 10.—Sweep-back and washing-out wing twist.

In spite of this, wing-tip slots are rather efficient in delaying the stall at the tips of a swept-back wing and in curing the premature tip stall, even at substantial angles of sweep. As the thickness of the boundary layer has much to do with the effectiveness of a slot, it is vital to have the slot as far forward toward the leading edge as possible.

With automatically actuating slats of the Handley Page type, the profile-drag increase, caused by the provision of slots at high incidences, becomes very small indeed for flying at high and cruising speeds. "Letter-box" slots are not as effective, besides giving higher profile drag. The loss of efficiency is not only due to the slot interruptions, which are necessitated for structural reasons; as the slots are farther back on the chord, the thicker boundary layer in that region impairs their action. On swept-back wings, the slot proportions and location tend to become critical. Nevertheless, the Me.163 rocket-fighter of Lippisch, which has proved to have satisfactory flying qualities at Farnborough, had been equipped with rather crude-looking slots of the "letter-box" variety.

The effectiveness of wing-tip slots for the prevention of premature tip stall and for the retention of aileron control beyond the stall, was discovered and investigated in this country more than 20 years ago. After it had become common knowledge that such slots could be designed to fit all reasonable demands for safe and effective flying, unstalled and stalled, wing-tip slots were—with few notable exceptions—practically ignored. To-day they return for tailless aeroplanes as one of the devices which may become a necessity.

First to experiment with wing-tip slots for the prevention of tip stall on swept-back tailless aeroplanes was G. T. R. Hill (Ref. 30). The necessity for this arose on the Pterodactyl Mk. V military biplane (1933-34). The shape of the larger upper wing resembled that of the U-wing of Mk. IV, but to give a better field of vision the centre section of the wing had a narrower chord and a thinner aerofoil section. In order to equalize the corresponding local loss of lift, it had been given a larger incidence, i.e., a wash-in. This resulted in premature stall at the centre section, i.e., in a (desirable) root stall. In flight with engine on, however, the slipstream of the tractor airscrew unstalled the centre section again, which rendered trim and stability difficult in powered flight. A remedy was found in the provision of automatic slots at the wing tips. These were coupled to a lift-spoiler, which emerged from the upper surface of the centre section as soon as the slots opened at high incidences. The slots began to open at an incidence of 10 degrees; they were fully open at 15 degrees.

As mentioned, wing-tip slots contribute little to the wing's maximum lift. But since they permit safe flight at the incidence at which the maximum lift of the entire wing system occurs, they allow a swept-back wing to reach a higher value of maximum lift than it would attain when no slots were provided. Wing-tip slots are, therefore, welcome accessories to high-lift devices for tailless aeroplanes.

With tailless aeroplanes and gliders several kinds of wing-tip slots have hitherto been used, such as (a) permanently open slots or fixed slats; (b) fixed slots with automatically operated shutters; and (c) automatic slots of the Handley Page type.

Fixed slats were experimented with in wind-tunnel tests by the N.A.C.A. a number of years ago, and the "letter-box" slots of the Lippisch Me. 163 have already been mentioned. The latter arrangement, consisting of one slot row interrupted by rib members of the wing structure, proved simple and effective. But it is open to doubt whether the increase of the profile drag caused by such slots can be considered tolerable at small incidences and high lift. Even if the direct loss in profile drag should be small, due to the influence of sweep—there are no experiments yet accessible of tests in this direction—it would seem obvious that the laminar flow over the region concerned is spoiled. In view of the somewhat crude execution of the arrangement, this is, perhaps, a feature the designer wanted in order to safeguard controllability and stability.

The Handley Page auto-slot has been successfully applied to the second version of the de Havilland D.H.108 tailless research type. It is actuated by the negative pressures over the wing leading edge, which assume high values, producing an upward, forward-directed resultant force on the slat when the lift assumes higher values. These high local negative pressures are the result of the adherence of the boundary layer to the wing, and a thin and vigorous boundary layer is a necessary requisite. The span-wise flow component on a swept-back wing causes the accumulation of a thick layer of stale boundary material at the wing tips. At the tips of wings with 45 degrees sweep, a boundary-layer thickness of between 30 and 50 per cent. of the local wing chord has actually been measured near the leading edge. Such a very thick boundary layer is lacking flow energy to provide high negative pressure, especially when the wing has some wash-out for stability. The experience with the second version of the D.H.108 has, however, proved that automatic tip slots operate quite normally.

To be continued)

Stalling Phenomena and the Tailless Aeroplane—VI

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

The previous Instalment of this article appeared on page 47 in the issue for July 11 last.

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.

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 the provision 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 wash-out 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-

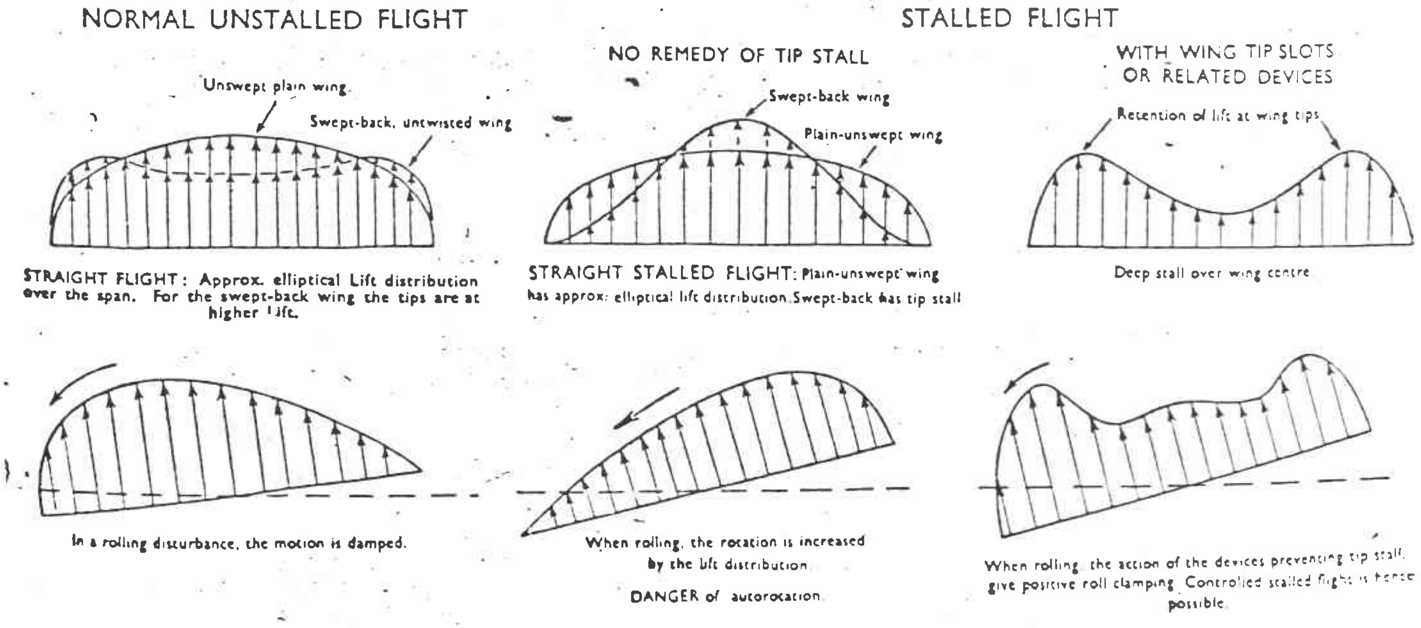


Fig. 11.—The Importance of the spanwise lift distribution for flight in stalled attitude.

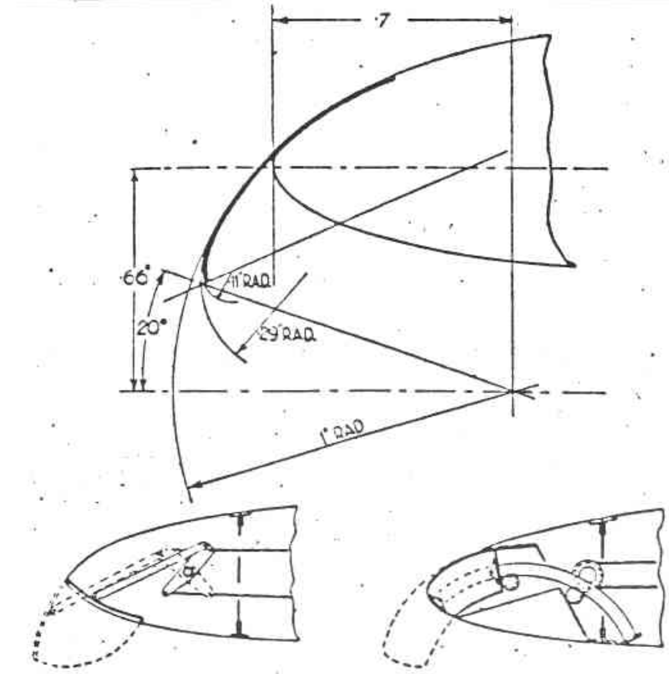


Fig. 12A.—(Above) This nose flap for a wind-tunnel model, proposed by C. G. W. Ebbutt in 1937, gave an increase of 23 per cent. in measured maximum lift coefficient. (Below) Methods of operation of two versions of suggested full-scale Ebbutt nose flaps.

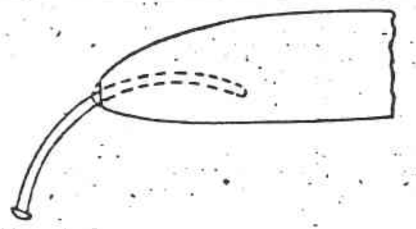


Fig. 12B.—A German example of a nose flap for tailless aeroplanes.

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.

Ebbutt claimed, on the basis of wind-tunnel tests, a maximum-lift increase of 23 per cent. 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 Gottingen 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.

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 the aircraft suffered from tip stall.

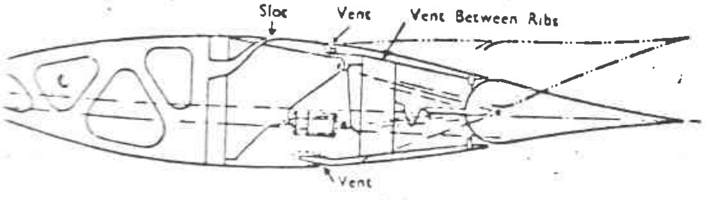
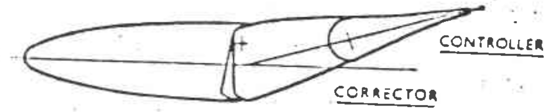


Fig. 13.—Boundary layer suction as applied to the Armstrong Whitworth A.W.52G experimental glider.

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 per cent. 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.

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



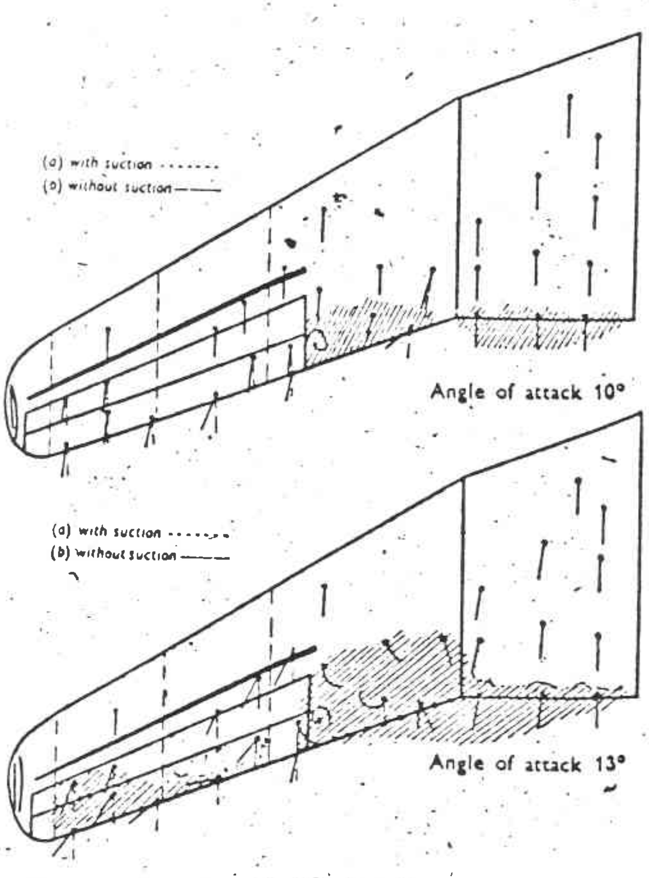


Fig. 14.—The effect of boundary layer suction on the Armstrong Whitworth A.W.52G glider at two Incidences. The position of the streamers indicates the effect. Regions subject to stall without removal of the boundary layer are hatched.