No. 311 MAY 2012

# T.W.I.T.T. NEWSLETTER

http://www.scalesoaring.co.uk/VINTAGE/Documentation/AV36/AV36.html

**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., **1205** means this is your last issue unless renewed.

**Next TWITT meeting: Saturday, May 19, 2012, 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.

## T.W.I.T.T. Officers:

**President: Andy Kecskes** **(619) 980-9831**
**Treasurer:**
**Editor: Andy Kecskes**
**Archivist: Gavin Slater**

The **T.W.I.T.T.** office is located at:
Hanger A-4, Gillespie Field, El Cajon, California.
Mailing address: P.O. Box 20430
El Cajon, CA 92021

**(619) 589-1898 (Evenings – Pacific Time)**
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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).

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## PRESIDENT'S CORNER

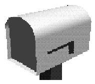
I really like this month's issue since we get to welcome back Paul Spatrisano and see what he is up to in the R/C model world of flying wings. He is laying the groundwork for developing a Horten type wing using a Klingberg wing as the basis. I don't know if anyone has been successful in this endeavor in the past, but it sounds like he has a good game plan in mind and has been corresponding with Rol Klingberg and Al Bowers to help make it work. I hope we will have more to report in the months ahead as he works his way through the process.

I have also finished the last segment of the Weyl article on Wing Tips for Tailless Aeroplanes. I hope you enjoy reading some of these older papers that in many cases laid the groundwork for some of the more modern concepts. In the case of the wing tips, I would think it could give you some ideas on taking a different approach to wing tip design, especially on a model.

I will be adding some documents to the members only section of the web site in the weeks ahead, so visit it from time to time to see if there is anything new. I would like to thank Paul for some of them and some will be reconstituted versions of the Weyl papers and perhaps some others that I have found in the archives. I just have to find the time between the two newsletters, working on the sailplane and still having a professional career.

I would like to hear from more of you about your projects whether they be big or small. Sharing your successes and failures makes it easier for other members to avoid the bad and take advantage of the good and move along faster on their projects.

Andy



## LETTERS TO THE EDITOR

Hi Al (Bowers),

I have been a long time member of TWITT and have been very impressed and thank full for all the contributions you have made to the group. Your deep interest in the aerodynamics of the Horten designs and the path you had to travel to figure out their bell shaped span load design philosophy in all its detail has been the key for me in understanding how they designed their wings-thank you. I have been doing the same since I first saw the Horten IV at Chino in 1970 (but I'm not a real aerodynamicist-just an amateur one)!

I have all the TWITT Newsletters from the beginning, Karl Nickels book, the Horten/Selinger book and a boat load of research on the subject from all over-but the way you bring it all together (plus your use of computers for analysis) in a cohesive way has truly advanced the knowledge for everyone regarding the Hortens.

I am writing you in the hope that you can share with me the individual rib AOA's for the 2 meter Klingberg wing that Mike Allen used to make the model that flies like a Horten should. My intention is to hot wire one from a properly twisted foam core with a straight leading edge, not arched. I have attached a file that I did in CAD to compare the AOA of each rib using the tapered building jig in the kit by Klingberg (page 1) to the information I got from the internet quite a few years ago regarding the change to the building jig per your input from Mr. Udens (page 2).

What I did was figure out the airfoil for each rib, prop each rib up according to the dimensions for the kits building jig and then do the same for the one that Mike used per your calculations. I then located each rib properly for a straight leading edge (swept per the kit in plan view) and got what I consider quite excessive twist-see attached PDF page 2. I obviously did something wrong (I think) and the only way I can be sure of the correct twist distribution is if I have the AOA of each rib.

I have attached a file with my correspondence with Rol Klingberg FYI.

The original Klingberg wing I built exhibited all the same issues with adverse yaw when turning described by all the various discussions in TWITT and elsewhere on the web. I finally got it to turn properly by rigging elevon differential into the mixer (the sliding servo box per kit plans). To initiate a turn I would input full stick up and full turn in the direction of the turn for several seconds. This would give full up elevon on the down going wing half and virtually no elevon movement on the opposite wing half. The momentary drag from the up elevon would get the thing to start turning properly them I would let the stick return to center and then gently complete the turn with normal control inputs.

Anyhow, what I want to do is build a 2 meter wing that I know will fly as a Horten wing would with proverse yaw and stability to use as a baseline for performance for some other designs I have in mind-L/D, in flight stability, maneuverability and so on. I am especially interested in tip tail flying wings-I have most of Kentfields research papers about what he calls OHS (Outboard Horizontal Stabilizer) aircraft and a paper on a small R/C OHS test bed that Scaled Composites made (along with their conclusions). I have attached a paper on the Blohm & Voss 208 I found on the web if you are interested (I'm sure you know all about it)! *(ed. – This is a 108 page Naval Postgraduate School Thesis titled "Analysis of a Semi-Tailless Aircraft" Design by Kurt W. Muller, March 2002. Due to its length I will put it in the members only section of the web site so you can download it for reading at your leisure.)*

I would appreciate any help or guidance you can give regarding the Klingberg wing or if you have the basic information to allow me to create a more Horten like 2 meter or so R/C model (airfoils, taper ratio, sweep, twist, control surfaces etc) that maybe you don't have the time to construct. I don't possess enough knowledge to do the aerodynamic design.

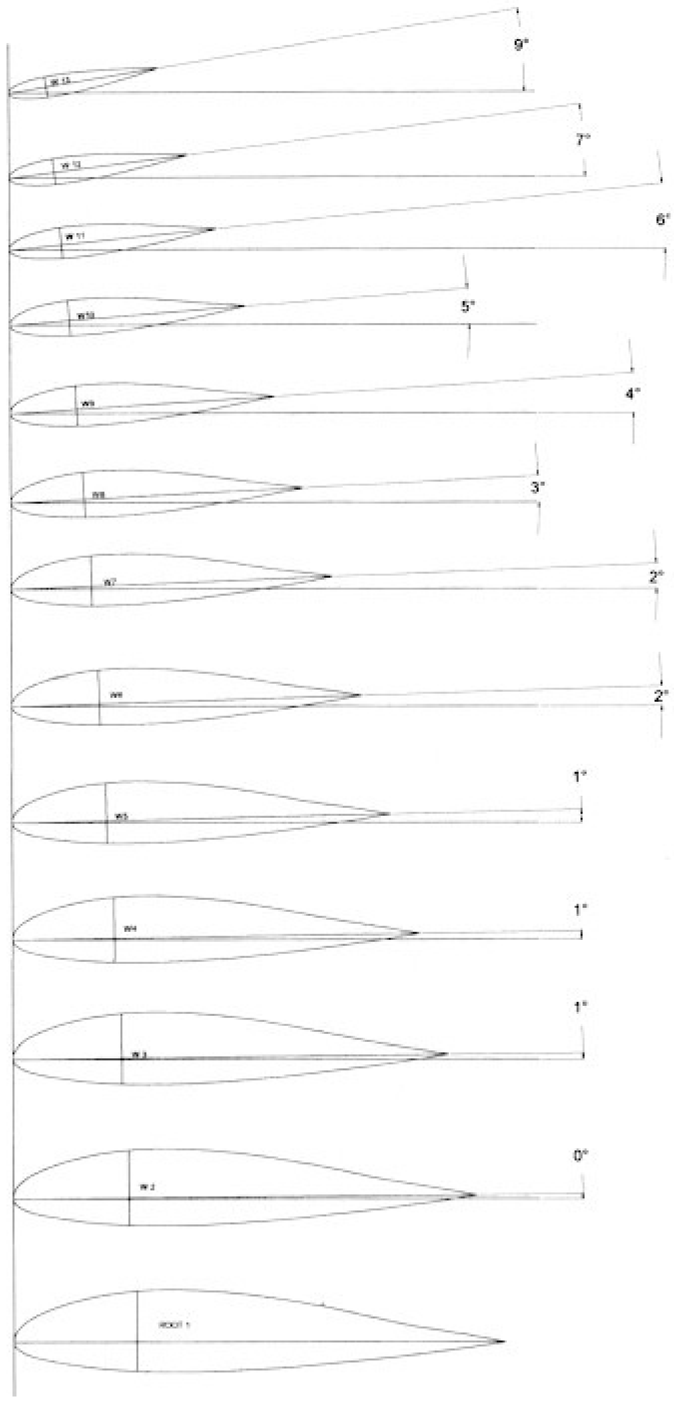
I would normally do this communication through TWITT but I don't want to be held to a schedule or commit to something I cannot complete-I will of course share anything I find out with TWITT as I go along.

Thanks -I hope this of some interest to you!

Paul Spatrisano

*(ed. – I know there have been others in the group that asked some of the same questions in the past or have experimented with changes to the Klingberg wing. So if you have any advice for Paul, please send them to*

**Standard Klingberg Twist**

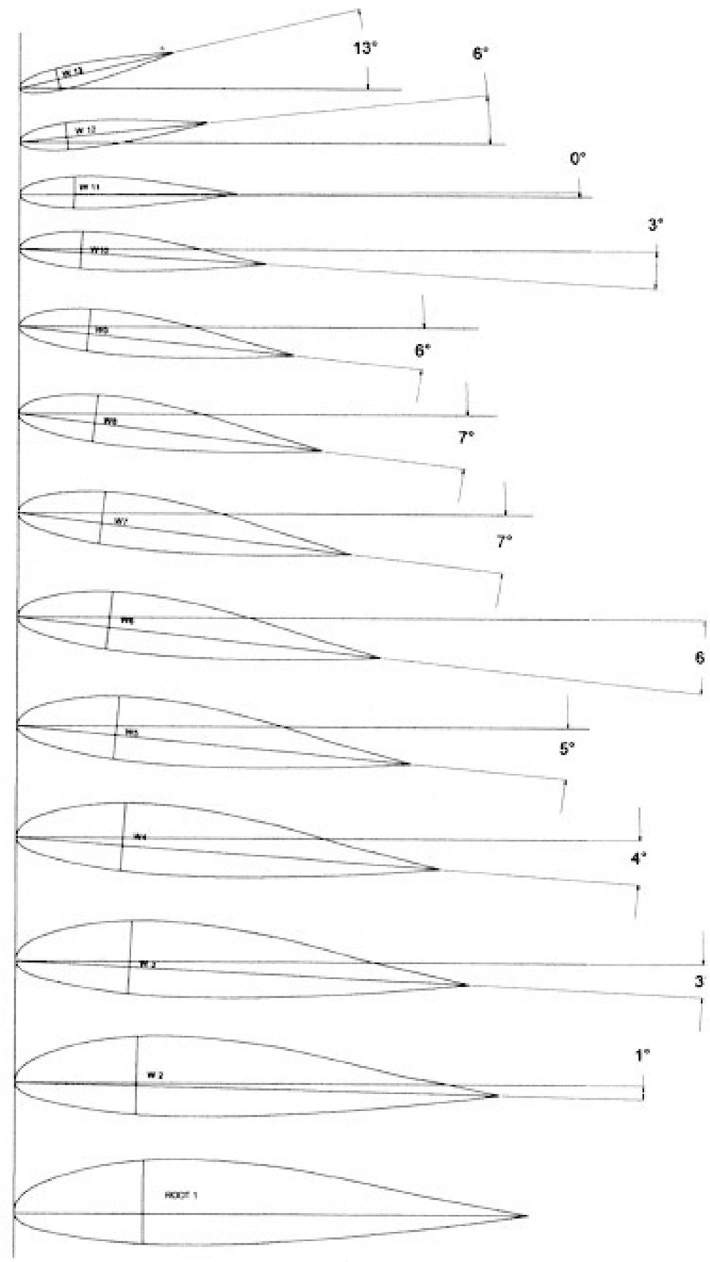



*me and I will forward them along and put them in next month's issue so everyone benefits.*

*I will also put on the members only section the other attachment Paul included that shows the modified Klingberg that has been published in a past TWITT issue.*

*Starting on the next page I have included the correspondence Paul had with Rol Klingberg so you*

**Al Bowers Twist**




*can get an idea of how Rol approaches such changes to his design.)*

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Hi Paul,

The twist angles that Mike Allen used are attached *(top of next page)*. I'd really like to hear your experiences on how this works. Something to keep in mind, there can only be ONE straight line on a wing twisted this way, and it is NECESSARY for the elevon hinge line to be straight (which means the leading edge and trailing edge must be curved).

Regards,

Al Bowers

Twist in degrees (20 stations from root to tip)

| | |
|---|---|
| R0 | 8.3274 |
| R1 | 8.5524 |
| R2 | 8.7259 |
| R3 | 8.8441 |
| R4 | 8.9030 |
| R5 | 8.8984 |
| R6 | 8.8257 |
| R7 | 8.6801 |
| R8 | 8.4565 |
| R9 | 8.1492 |
| R10 | 7.7522 |
| R11 | 7.2592 |
| R12 | 6.6634 |
| R13 | 5.9579 |
| R14 | 5.1362 |
| R15 | 4.1927 |
| R16 | 3.1253 |
| R17 | 1.9394 |
| R18 | 0.6589 |
| R19 | -0.6417 |
| R20 | -1.6726 |

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Hi,

I am wondering if you still have available plans or kits for your 2-meter radio controlled "Klingberg Wing" glider? I had one that I built about ten years ago but was destroyed in a high-speed ridge lift crash (Monokote bag of balsa powder). I thought that I still had the plans to make another one but they are gone. Can you help?

Thank you in advance,

Paul Spatrisano

Paul:

I have construction sets available. They include full size plans, jig pattern, extensive photo illustrated instructions (including conversion to gas and electric), and finally, sticky backed parts patterns which greatly speed the cutting of parts. If you want one send $25 to: Rol Klingberg 1345 Westridge Dr. Portola Valley, CA 94028.

Rol,

I received your plans last week. Thank you very much. I am impressed with the thoroughness of your instruction package and quality of the plans. I was not aware that your wing was designed by aeronautical engineers - very different from many kits out there. The peel and stick parts patterns are a great idea.

As I am a perfectionist, I would like to plot and print the ribs myself (I use Ashlar Cobalt-a 3D design and modeling program) and am wondering if you would allow me to do so? It seems that the center rib is a NACA 23015 that begins to transition somewhere about 1/3 of the half span to the tip into an airfoil (custom design?) that I haven't figured out yet. I would of course treat any information you give me with absolute confidentiality. A text file with coordinates of each rib or just a description of the transition point and the tip rib airfoil would work (assuming I am correct in my assumptions!)

If the center rib and a portion of the wing is a NACA 23015 section, does a laminar bubble form at the angle of attack and or Reynolds numbers that this craft normally flies at? If it does, does it bleed off due to sweep (eliminating the bubble)? Or does the spar step (where the leading edge sheeting transitions to the covering) trip the bubble? Or does the bubble help in some way? I just gotta know! I guess what I really want to know is if I build this wing fully sheeted and smooth (without increasing the design weight) in your opinion will it be more efficient? That is the other reason I need the coordinates for the ribs as they would be modified to allow thinner sheeting to be used aft of the spar on top of the wing and thinner sheeting on the bottom of the wing. Thanks again,

Paul

Hi Paul:

I can see that you know your stuff, but on the other hand I have of course a great deal of asset value in my products. As with all these types of products I keep all design information fully covered by copyright and I do not distribute that information. I'm glad you are happy with the product and I hope you enjoy your wing.

Cheers,

Rol Klingberg

Rol,

That's fine-I understand. Thanks anyway. This is only a hobby for me and I have yet to meet anyone in my circles whose eyes don't glaze over at the suggestion of flying wings. I am just very interested in deciphering the aerodynamic nuances of a truly stable and efficient flying wing (kind of like people that play chess I guess).

Actually, awhile ago I found an internet article that was written by an employee of Al Bowers (an aero-dynamicist working for NASA who is very interested in flying wings, particularly in Horten twist distributions) that describes the conversion of one of your wings to a sine 3 lift distribution (the guy that did the calculations used to work for the Hortens) to see if pro verse yaw was created in turns with normal control deflection - it was (probably at the cost of some lift). Problem was that he just changed the shape of the spar building support, which resulted in a curved leading edge resulting in the addition of dihedral etc (as well as a change in elevon design). I want to build one correctly with the correct washout at the trailing edge. I have the twist information but it needs to be laid out correctly before I can build. It might be a very docile handling (easy to fly for beginners) wing.

I want to build one of your wings stock and one with sine 3 twist and compare them in flight. I intend to use these as a baseline for further designs to explore the efficiency and stability of flying wing aircraft for my own edification.

The other thing is I have the co-ordinates from an old article that allow the reshaping of the top of the NACA 23015 airfoil to supposedly eliminate the laminar bubble-which I think the Klingberg Wing has (see attached). I did not realize that your wing uses the NACA 23015 (if it does) until I received the plans and started to check things out.

I would be happy to share anything I find out.

Paul

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I got hold of this original source document of The Horten Tailless Report, scanned it and cleaned it up. I suggest that you put it in the members only part of the website for all to enjoy…….it has no copyright as it is an intelligence report. *(ed. – This report was prepared by the Combined Intelligence Objectives Subcommittee, London – H.M. Stationary Office, May 1945, by F/Lt. D.C. Appleyard, MAP, and Lt. Cmdr. M.A. Biot, USNR. I will be placing in the members only section of the web site for now.)*

I will also be sending you a disc next week with twenty 18" x 24" original Horten IV factory drawings (copies I'm going to get scanned) to post on the website also-I'm going to have them scanned early in the week. They are not complete as the center section drawings are not there, but the steel carry through spar and the individual parts needed to complete the welded carry through spar assembly are. They really shed light on some of the important construction details. The outer wings to the tip are all there, including the intricacy of the metal wing tip structure, the control surfaces and so on.

The drawings are likewise not copyrighted.
If anyone has the rest of the drawings gathering dust I would be happy to get them scanned-just send them to me @P.O. Box 8210, Bend, OR, 97701 and I will be sure to return them quickly in the same condition I received them.

Paul

*(ed. – I will be putting these in the members only section of the web site. I will also make a comparison to the similar drawings we have in the archives to see what we have that may be missing from Paul's set and try to get everyone as complete a set as possible.)*

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I have got a small problem with finding out my renewal date (I do know its quite a while yet..)

By the way the Colditz escape glider is called The Cock, and the UK Channel 4 TV is going to go for a reenactment with a replica in August at Colditz castle. (Not quite flying wing, but of interest, as you linked to Fidders Green, (thank you) who do a paper version, wrongly named...
FYI an R/C Model magazine in UK did a very semi-scale DUNN biplane plan recently.

Yes I do enjoy the newsletter a lot.

At the age of 10+, just after the war, I was drooling over the new fangled Jetex 50 re useable rocket motors for model aircraft when an Uncle came back from the war & said he would design me a real model, named the BAT.

Memory says is was a very Horten design, though he did get carried away a little and it ended up 7 ft wing span, and needed half a Balsa tree - just a little beyond my ~25c U.S. weekly pocket money, but I did spend many hours dreaming over the immense beautiful plan (drawn on wall paper). It got lost at some time or other in a house move but the dream lives on.

I really must buy 2 new 27mm electric ducted fan motors, and fit them to my 18 inch Depron R/C AW52 that has sat on my bench for 6 years now. It flew okish with a pusher brushed motor, but was not convincing.

Best regards.

Mike Briggs

*(ed. – Mike lives in Cranfield, UK and receives his monthly issue via an e-mail attachment, therefore there is no mailing label to let him know his expiration date. We have a couple of members receiving it this way so I send them an e-mail approaching their expiration date so they don't miss an issue.)*

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I am becoming interested in the Mitchell Wing U-2 Superwing motor glider.

I'm guessing that among my fellow TWITTs is someone who knows where a U2 is. I don't want to fly it, just look at it, and verify that all 6' 1" of me will fit inside. Watching someone else fly it would be a bonus.

So, if you are a U2 owner, builder, flyer, or just know where one is, let me hear from you.

One exception, if you've never seen one, flown one, built one or known or heard tell of anybody who has, but do feel some deranged compulsion to belabor total strangers with a reply, please spare me and others, and save the story for the next visit with your therapist.

Anyway, those with real U2 knowledge or experience, lets hear from you.

Cordially,

David Bogart
305 Walnut Street
El Campo, Texas 77437-295
dave.bogart@yahoo.com

*(ed. – Obviously David would like to find one in the general area around Texas to reduce the travel experience, so if you have a contact point for him, please pass the information along. The U-2 Yahoo group might be another source of information, but it always seems from the message traffic that they are asking a lot of questions but there are few actual aircraft in the inventory.)*

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Bob (Hoey),

Hello, Just a quick email to ask about obtaining a set of plans to build a seagull.

I will be finished with my current military tour in January and will be moving back to Germany. I am looking at building a bird like model for slope soaring when I get there.

I have a set of plans for a Stephen Winkwort Pteranodon and was planning on building it; however I have read on line that you have built this model and tried to improve its some what poor flight characteristics but could not get it to fly as well as you would have liked.

Before I put the Pteranodon build on hold I would like to know if what I read on line is indeed true.

If so I will put the Pteranodon build on hold and build a gull instead, that is of course if I can obtain some plans. If not I will build the turkey vulture.

Please let me know if a set of gull plans is available and how I might purchase them.

Thank you for your assistance.

Regards,

Joseph Pikal

Hello, Joseph,

I worked for several months, BEFORE hearing about Winkwort's plans, trying to devise a Pteranodon model that would fly, My approach was to assume that their neck probably folded back like that of a Pelican, which would place that vertical topnotch farther aft and in a less destabilizing location. I received Winkwort's drawings later, but never built his model. It was a very complex structure, so I just continued to work with my simpler designs. You are correct that I never got a Pteranodon model that would fly, but I never tried

Stephen Winkwort's design, so can't comment on it's flight characteristics. (If you do build one, let me know how it flies!)

My seagull plans are fairly crude working drawings, since it was never cleaned up and published anywhere. Several builders have successfully built the bird from these drawings and you are welcome to give it a try, free of charge. Just send me your snail-mail address and I'll send you a copy.

If you decide to build the Turkey Vulture, be advised that I have reduced the wing dihedral from 8 degrees per side (shown on the drawings), to 5 degrees per side and it flies better. Less rolling oscillations and easier to control.

Both the vulture and the seagull models have been successfully slope soared.

Bob Hoey

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**September, 1945 AIRCRAFT ENGINEERING**

## Wing Tips for Tailless Aeroplanes

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

**The Rams-Horn Vortex and Related Phenomena**
(continued)

Saenger assumed that all these partial effects, with the exception of the last one, would only result in an increase of the profile drag, due to increased vorticity and increased surface friction. His tests with aerofoils having rectangular shape anti bird-like cambered sections confirmed this. Indeed, a very large number of aerofoil sections having concave lower surfaces are known to exhibit peculiarities and abrupt changes in the air flow which are consistent with the view that, below certain characteristic angles of incidence which lie at small or medium lift coefficients, something like the flow phenomenon described above takes place on the lower surface. These aerofoil sections, have, in general, a thick and bent-down nose (Phillips Entry) which thins rapidly toward the trailing edge, and an accentuated camber which reaches its maximum aft of the 50 per cent station of the chord. Examples of such aerofoil sections are the Goettingen sections 232, 252, 263, 370, 393, 394, 395, 396, 400, 448, 450, 461, 462, 464, 652; Eiffel 36; Durand 10; N.A.C.A. 97, 4409, 4412, 6712, etc. Moreover, normal aerofoil sections with high-lift devices of the plain-flap type may exhibit similar peculiarities when the flap is operating, while in slotted wings an opposite effect seems to be present. From a comparative test (Goett. 481 and 481A) it is evident that when the cavity on the lower surface is filled, the drag at small incidences improves greatly, while the maximum lift suffers (camber effect), and while the drag at incidences near the stall is somewhat deteriorated. At the characteristic incidence of flow transition in such aerofoils, the pitching moment is also affected, indicating a variation in the pressure distribution around the section (Goett. 464).

A span wise ridge along the lower surface behind the leading edge does not seem to be essential for the discontinuity effect. But to judge, from the Goettingen tests published, genuine Joukcowsky sections seem remarkably free from the change in flow. This might indicate that the variation of section thickness from nose to tail is linked with the behavior of the flow. Centrifugal forces acting on boundary-layer material are presumably of great importance upon the formation of the vortex.

Aware of the possibilities of changing the fundamental characteristics of a wing by varying the lower surface, L. Breguet suggested covering the cavity of the concave lower surface by an elastic fabric and connecting the space between the wing surface and this elastic envelope with the outer atmosphere by a duct opening forward against the relative wind, so that the entrance slip is parallel with the wing chord at zero-lift angle of incidence. Thus at small incidences, a concave lower surface is formed, while at large incidences, a convex lower surface becomes effective.

Most decidedly, the phenomenon is particularly sensitive to scale effects N.A.C.A. tests on the influence of the Reynolds number leave no doubt about that. The early Goettingen tests were made at Reynolds numbers of 79,000, the later ones at those of 440,000. Both indicate the presence of the vortex formation in aerofoils having square tips. The N.A.C.A. tests seem to limit the range of the effect down to below 170,000.

Further, it seems that, at very low Reynolds numbers the effect as expressed in the polar diagram may actually be reversed and even discontinuities of the lift curves may well appear.

The result of the presence of the vortex is that the lift/drag ratio experiences an abrupt improvement at a characteristic incidence; at this incidence, moreover, two distinct values of drag seem possible. Below this characteristic incidence, the drag is much increased. The deflection the of a flap forming the trailing edge has apparently no profound influence, and also leaves the characteristic angle unchanged, an indication that this angle depends on the nose shape. Downward deflection of the flap accentuates the change of flow. In extreme cases (Goett, 652), the drag at the characteristic incidence can drop to as little as 35 per cent of its original value.

Saenger's tests established that with plain aerofoils having such sections and square tips, a standing vortex is formed in the cavity which rotates in a sense which is opposite to that of the lift-producing circulation. It was not observed that the vortex shifted in its axial direction. At the tips the usual equalization of pressure took place and normal marginal vortices were shed. The characteristic incidence was about 8 deg.

By the addition to this wing of positively raked, tapered and downward-tilted tips, an axial shift of the vortex toward the tips took place, especially at negative incidences. The characteristic incidence decreased to 1¼ deg. for a pointed and to 6 deg. for a blunt tip. The latter was, however, in general superior to the pointed one, especially at larger incidences. In the range of the optimum incidence (maximum lift/drag ratio), which was just above the characteristic incidence of flow change, the vortex was less in appearance. No span wise flow was observed beyond the tips. An accentuation of the tilt of the tips improved the flow there. Span wise stiffeners running within the cavity of the lower wing surface did not seem to affect the flow characteristics to a noticeable extent.

Saenger's tests were made at a Reynolds number of approximately 132,000, i.e. well within the range mentioned above. At equal incidences, the profile drag of the three arrangements investigated does not differ greatly, while the lift coefficient is 70 per cent greater with the diffuser tip as compared with the plain root angular aerofoil.

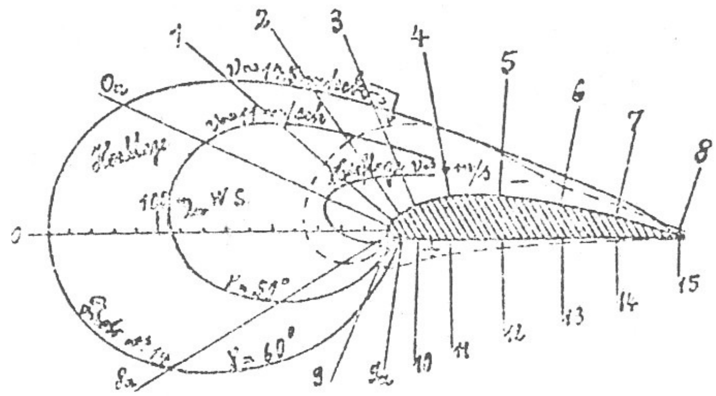
R. Schul also claimed in favor of his diffuser tip that it gave not only improved stability, but also a decreased formation of marginal vortices, hence an increased lift and a decreased drag.

In wing systems having an effective sweep-back, an intensified action of the rams-horn vortex can be expected, since the flow component due to sweep-back encourages the span wise shift of the vortex.

This might explain the aerodynamic superiority of sailplanes such as the Weltensegler, which have a bird like shape.

**The "Oblique-Attack" Effect**

Quite a different phenomenon of transverse flow was observed and studied by F. Budig, an independent aerodynamical experimenter.



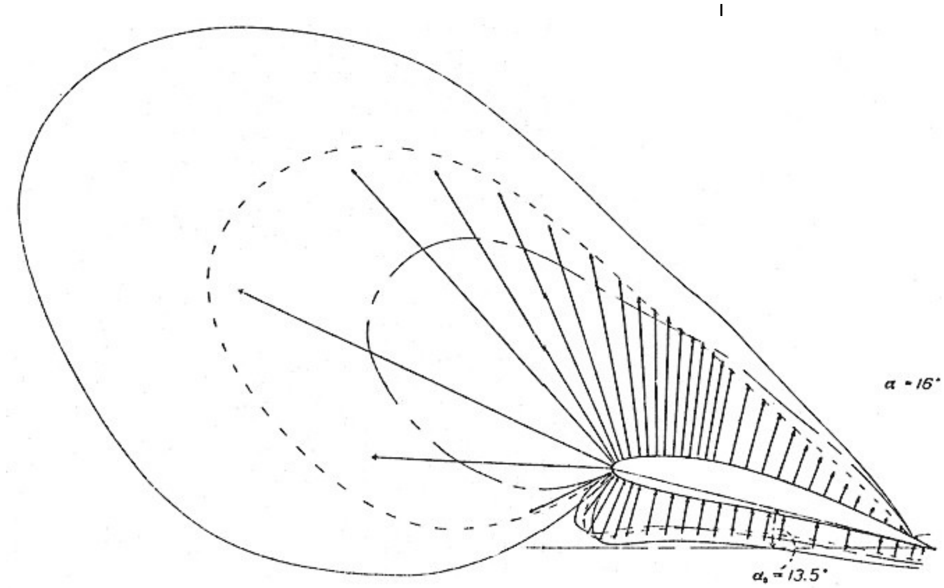

*Figs. 11(a) and 11 (b) -- Pressure distribution (vector diagrams) under "oblique attach" and according to the hydrodynamic theory.*

*Above, Budig's measurements under oblique attack. Tests made in natural wind (48 ft./sec.) with a full-scale rectangular wing of Goett. 387 section. V is the angle of side-slip; in addition, the wing is tilted at 30 deg. to the horizontal. The angle of incidence is 14.5 deg.*

*"Hochlage" = high end of the tilted wing; "Tieflage" = low end.*

*The dotted lines represent measurements in the Goettingen wind tunnel at normal attack, but otherwise corrected to the conditions of the test.*

*Next page, theoretical pressure distribution of potential flow for an N.A.C.A. 4412 aerofoil section at an incidence of 16 deg (from R. M. Pinkerton, N.A.C.A. Tech. Rep. 563). The full and the dotted lines represent flow without viscosity of an aerofoil of infinite span. The broken dotted line refers to a lift equaling that of an aerofoil at an incidence of 16 deg., i.e. corresponding to an incidence of 13.5 deg. of the theoretical lift. The vectors (arrows) give the actually measured pressures in the centre line of the aerofoil for a test at a Reynolds number of approximately 3 x $10^6$.*




In 1916, while investigating in flight the pressure distribution on the ailerons of experimental biplanes, by the means of multiple manometres, be noticed the profound and detrimental influence of side wind (side-slip) upon the control efficiency of the ailerons. Overbalancing and dead-centre action became apparent. About 10 years after this, Budig found occasion to investigate the matter further and he then discovered what he termed the "oblique-attack" effect. This refers solely to flow over the dorsal surface of a wing when it is exposed to a side-wind.

The discovery claimed by Budig was not the first observations of this kind. For instance, F. H. Wenham mentions, in 1866, that he found the fluid force exerted on a plate moved transversely to a flow of water to be greater than that experienced when the plate remained motionless in the fluid stream.

According to Budig, a wing under an angle of yaw experiences a span wise deflection of the air upwards of the stagnation point at the leading edge. This deflection is responsible for a profound change in the airflow over the upper surface. The deflection may be caused by side-slip, by sweep-back, or by a wing tip having positive rake. A rectangular wing under an angle of bank and of yaw is particularly susceptible to the effect.

The result of the air deflection at the leading edge is, Budig claims, a spreading out of the streamlines over a wider region of the dorsal surface and thus, without separation of the airflow from the surface, the formation of abnormally high negative pressures at that part of the leading edge which is facing the relative wind (i.e., in a side-slip, the leading wing). This abnormal low-pressure region not only increases the lift but, due to the forwards inclination of the resultant aerodynamical force acting at that region, also decreases the drag to an extent, that it may become, negative for the wing part concerned.

As, according to Budig, the "oblique attack" prevents separation, the negative pressures at the exposed leading edge may grow considerably with incidence even far beyond such incidences, at which normally stalling would set in. Otherwise, at small angles of incidence, the effect is far less accentuated.

Wind-tunnel tests made in closed-jet tunnels by the Goettingen Laboratory have shown no agreement with the experimental observations of Budig. This is not necessarily evidence for the non-existence of the "oblique-attack" effect, since, by their nature, wind-tunnels are apt to suppress phenomena of span wise flow, and disagreements of wind-tunnel tests on yawed wings with the results of experiments in flight and with theoretical calculation are known to exist. Budig has made his experiments on full-scale wings in the natural wind over land (aerodrome surface) and water at Reynolds numbers which would seem to be comparable with conditions of slow flying. He has also made tests in water. His experimental installations were actually approved by the German Research Institute for Aeronautics (DVL), subject to inaccuracies caused by gustiness and ground influence; moreover the DVL then stated authoritatively that the negative-pressure phenomena observed seemed "entirely in agreement with experiences gained elsewhere. Large-scale investigations made in a French wind-tunnel at Chalais-Meudon by Rebuffet seem to confirm Budig's observations. Considerable negative drag (i.e., a thrust force) was measured at 29 deg. incidence under 45 deg. of side-slip.

Experiments made by Haller in Zurich proved the existence of an "oblique-attack" phenomenon on vertical surfaces situated above a tail plane, by which an aerodynamical force increasing a spinning motion of the aeroplane is produced. Previously, Budig had already pointed out that oblique-attack played a large part in spinning.

The pressure distribution under oblique attack at or near the leading edge as observed by Budig, agrees in shape and magnitude closely with the theoretical pressure distribution which can be calculated on the basis of potential flow with the help of Bernouilli's equation. It would thus appear conceivable that the oblique-attack effect could make up for the influence of viscosity in the boundary layer. From the boundary-layer theory it follows that by removing the boundary layer (for instance, by sucking it away) flow patterns can be achieved which closely approach those of genuine potential flow. O. Schrenk has pointed out that it is, for this, not necessary to remove the entire boundary layer, and that a sort of "relay action" has been proved to exist. If so, one possibility is that the oblique-attack as observed, could be the result of periodic vorticity over the wing parts affected. As E. G. Richardson has stated again, such periodicity is not identical with a turbulent boundary layer, but the final effects are not dissimilar. This refers particularly to the delay of boundary layer separation from the surface, thus giving higher lift values and less drag at higher incidences. Even the contention of a negative drag by Budig is consistent with the assumption of periodicity in the boundary layer. That mere vibration of a wing may raise the maximum lift considerably must be considered a fact; it has been experimentally confirmed by wind-tunnel experiments of M. Denis at St. Cyr, and observations in flight are in agreement. Even the Katzmayr (Kroller-Betz) effect points in that direction and seems, with its periodic fluctuations in the boundary layer pattern, related to the oblique effect.

On the other hand, when evaluating the observations of Budig, it must not be overlooked that, since Budig made his experiments in natural wind which fluctuates in direction and velocity, phenomena of non-steady lift (hysteresis effect) due to inertia of the boundary layer may have influenced the somewhat baffling results. At the time that Budig staked his claims for an aerodynamic discovery (1930), phenomena of flow inertia and of non-steady lift arising there from had not yet been sufficiently explored. With regard to the discrepancy between his measurements and the Goettingen tests, Budig contended that it might well be that, for the oblique-attack effect, the law of dynamic similarity (Reynolds number) does not hold; he argued that great velocity of airflow might decrease the angle of deflection at the leading edge, and this angle decides the magnitude of the negative pressures.
On the strength of his discovery, Budig believed that obliquely-cut wing tips would be helpful to make auto-rotation impossible. Spinning trials on certain transport aeroplanes with tips resembling those of the Zanonia type, have indeed given some strength to this contention, though the case is one of considerable doubt, since lack of elevator power may also have contributed to the results. Budig also recommended the *M*-shape of wings (in front View) and of wing-like parts. In a side-slip, with wing tips of this shape, in Budig's view, the leading tip will not only be free from separation of the flow, i.e. from loss of lift due to stalling, but will, on the contrary, experience higher lift and diminished drag. Thus a stabilizing effect takes place.

Nearly all discoverers and experimenters of diffuser wing tips have also employed the tips for control purposes and/or trim: Dunne fitted curved controllers to both wing and tip; Schul suggested that control devices are best fitted to the ends of his "hollow cones"; Kupper attached not only controllers but splitting air-brake rudders to the diffuser tips of the tailless MU.5 sailplane; Huettmann employed tilting of the entire tip for control; Northrop used the same idea, but employed in addition controllers fitted to the wing tip.

One of the greatest advantages of diffuser tips for stability and control is that they will not be fundamentally affected by the stall of the lift-generating part of the wing. Though it has yet to be established if and how far a complete separation of flow at great incidences can be delayed by the effect of a diffuser tip, it seems fairly obvious that control by way of such tips will have an advantage by remaining less impaired at and beyond the stall of the aeroplane.

It will also seem that the diffuser tip is not only an interesting subject to explore for aerodynamical research, but a device which is of so much promise for practical application that it deserves more interest and study than it has received in the past.

http://www.bionik.tu-berlin.de/institut/xtutor1.htm

## AVAILABLE PLANS & REFERENCE MATERIAL

### Tailless Aircraft Bibliography

My book containing several thousand annotated entries and appendices listing well over three hundred tailless designers/creators and their aircraft is no longer in print. I expect *eventually* to make available on disc a fairly comprehensive annotated and perhaps illustrated listing of pre-21st century tailless and related-interest aircraft documents in PDF format. Meanwhile, I will continue to provide information from my files to serious researchers. I'm sorry for the continuing delay, but life happens.

Serge Krauss, Jr. skrauss@ameritech.net
3114 Edgehill Road
Cleveland Hts., OH 44118 (216) 321-5743

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