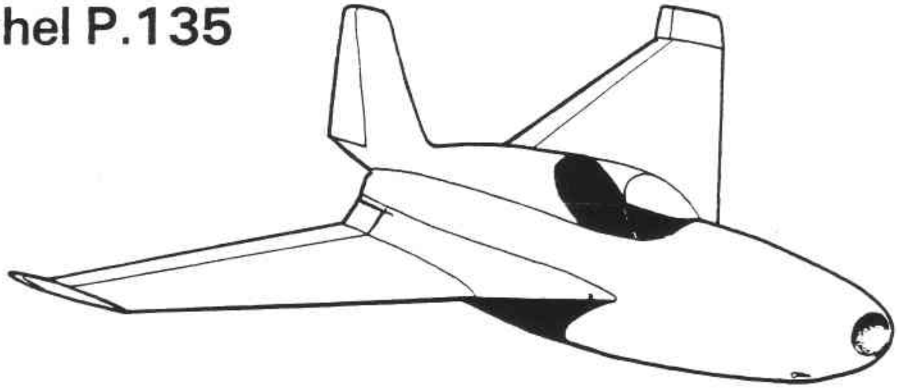
No. 67 JANUARY 1992

T.W.I.T.T. NEWSLETTER

Henschel P.135



This single-seat mid-wing jet fighter was designed as a private venture in response to the Emergency Fighter specification of 1944 (see FW Ta 183, page 57). It was to be a tailless aircraft with a single central fin. The semi-delta wings were set well back on the fuselage and fitted with dihedral tips. The single HeS 011 turbojet was mounted in the rear fuselage and fed by a nose intake. An armament of four MK 108 cannon was to be fitted, two in the wing roots and two in the lower nose. The scheme got no further than the project stage, being dropped when the OKL favoured one of Focke-Wulf's Ta 183 designs.

Henschel P.135 data

Role	Single-seat jet fighter
Ultimate status	Design
Powerplant	One HeS 011A turbojet, 2,866lb (1,300kg) st
Maximum speed	612 mph at 22,960ft (985km/hr at 7,000m)
Service ceiling	45,930ft (14,000m)
Weight	9,038lb (4,100kg) loaded
Span	30ft 2in (9.20m)
Length	25ft 7in (7.80m)
Wing area	220.6ft^2 (20.5m^2)
Armament	Four MK 108 30mm cannon

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

The number to the right of your name indicates the last issue of your current subscription, e.g., **9201** means this is your last issue unless renewed.

Next TWITT meeting: Saturday, January 18, 1992 beginning at 1330 hrs at hanger A-4, Gillespie Field, El Cajon, Calif. (First hanger row on Joe Crosson Drive - East 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 types of tailless aircraft by providing a forum for the exchange of ideas and experiences on an international basis. T.W.I.T.T. is an affiliate of The Hunsaker Foundation which is dedicated to furthering education and research in a variety of disciplines.

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Meetings are held on the third Saturday of each month, 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, east side of Gillespie).

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PRESIDENT'S CORNER

Well, here we are into another new year and it is time to start planning what TWITT will be doing to enhance its services to the members.

As soon as we have decided on a logo for the organization, we will be looking into getting some type of name tag and/or patch that members can wear to show their support for flying wings. If you are interested in this idea, please let us know through your letters or just a postcard. We will try to keep the price within reason so everyone can get one without it being a big pinch on tight budgets.

Bob indicated that some of last month's newsletters came back without any mailing labels attached to them. We are not sure is this is a problem at our end or with the way in which the post office handles this type of mail. If you did not receive your December issue, and should have, please give us a call or send a postcard so we can get them out to you.

I was sorry to see that we did not have much response to Karl Sanders initial article. Perhaps as the holiday season subsides you will all take to your typewriters and let us know what you think. Karl has provided some editing of the material that, unfortunately, didn't reach us in time for the December Newsletter.

I am hoping that the new year will bring forward some new projects, both full size and scale, that will help stimulate everyone's thoughts about the "best" type of flying wing. Don't forget, this is **YOUR** forum for learning how to solve problems and/or get in touch with people who can help advise you in areas where your technical skills may be weak.

Andy

JANUARY PROGRAM

Bob has planned a program around the one we showed at Tehachapi during the SHA Workshop. This will include slides on Mitchell flying wings, along with material on Hawley Bowlus' flying wing prototype he built for the Army Air Corps. Don Mitchell later modified it into a pure flying wing, but the project was later terminated by the Army.

We will also have a video copy of "The Wing Will Fly" that has been shown on The Discovery Channel last year and this past New Year's day. This is an interesting look into the development of the Northrop flying wings, up to the point that the B-2 was first flight tested. If there isn't time to show the whole thing, we will at least look at some of the many good clips of the various versions of Jack Northrop's wings.

UPDATE FROM KARL SANDERS

Karl provided us with some feedback on Bruce Carmichael's and Tasso Proppe's letters on page 5 of the December 1991 newsletter covering Karl's original essay.

1. Bruce is right. Anderson's method is not for swept wings.

2. I do not know of a British empirical sweep correction. However, the well known Alan Pope published a charmingly simple <u>and</u> accurate one in the <u>Journal of Aeronautical Sciences</u>, August 1949! See also McCormick "Aerodynamics of V/STOL," page 184.

Pope also gave his formula in his 1951 edition of <u>Basic Wing and Airfoil Theory</u> (an excellent text! - Covers everything I mention in my essay! Copy of relevant pages is attached.) *(Ed. Note: For those wanting a copy of the pages, drop us a postcard, since they may not reproduce in the newsletter very well.)*

3. (Concerning ellipticity and guarding against tip stall) Bruce is right; in fact I mentioned it in the beginning of my essay. It is especially applicable to gliders (constant ac, cg, weight, speed and Cmo. Essentially the trim equation is:

$(ac-CG)C_L + C_{Mo} = 0$ where
(ac-CG) is infraction of MAC
$C_L = W/s*q$ where
W = airplane weight
s = wing area
q = dynamic pressure
C_{Mo} due to: section camber
local camber (elevons)
twist
(Watch out for signs!!)

For high performance planes ac, C_L and C_{Mo} are varying with Mach number, and CG can vary by up to 20% MAC, so that trimming with twist is not very practical - if not impossible. Transferring fuel is then often necessary to control CG travel (if there's still enough on board to do it with...).

PROJECT EAGLE - About 10 years ago I made a conceptual design of a flying wing to compete with Rutan's Voyager. Here I was able to trim with twist, and used a fuel tank sequence to keep the first term above constant; that was necessary because C_L varied considerably with the (large) fuel load! That principal is called "self trimming."

Finally, be aware that twist for trim should reasonably match twist for minimum induced drag (elliptical loading) for the <u>average cruise</u> C_L. For all other C_L's there is an induced drag penalty! I published a technical note on that point in the <u>AIAA Journal of Aircraft</u> of July-August 1965 (p. 347).

4. (Concerning Bruce's last comments on Jerry Blumenthal's design) I would agree with Bruce. If you build a model, it's not too difficult to mount the wing such that incidence can be varied (shim or small lead screw). We did that in 1948 on a flying glider mock-up of a fighter prototype, using shims.

5. (Concerning Tasso's comment on birds having variable sweep) This is not to my liking. Variable sweep has a tendency to change stability when used for trim. You want to keep stability (the bracket in the first term in the equation above) constant during trim and control.

Page 4 of the newsletter also contained two items Karl noted needed correction. They are: 1) In the NOTE $C_{Mc/a}$ should be $C_{Ma/c}$, and; 2) Two paragraphs later (in % MAC) should read (and its relative position with respect to the CG, in % MAC).

Karl also contributed a copy of John Lamar's NASA TN D-4427C.1 mentioned in his original essay. *(Ed. Note: If you are interested in this and the earlier pages on Basic Wing and Airfoil Theory, send us $1 for printing and postage of both pieces.)*

HORTEN IA-38 KARL L. SANDERS 12/9/91

In the TWITT News #64 Phillip Burgers contributed a 3-view of the Argentine Horten IA-38. I looked in Horten's book "Nurfluegel" and concluded that it might have been the source. Unfortunately it is the wrong drawing - perhaps an early one, but not of the airplane that was built and illustrated by many photos in that book, and that I saw in the 1950's. Jane's All The World's Aircraft, Volume 1958/59, has it correct. I am sure Jane's lets you reproduce the attached copy with credit to them. This was an exciting project whose gestation period (1950-53) I daily witnessed, since both Dr.Horten and I worked at the Aerotechnical Institute of the Air Materiel Center (FMA) in Cordoba. It was a huge aiplane; Horten's and Argentina's biggest.

Here is a brief chronology as I remember it: 1) proposal and mock-up in 1950, 2) about mid 1951 engineering, jig and tool design begins with not more than a dozen mostly young argentine engineers and about the same number of draftsmen. Dr.Horten did most of the aerodynamics himself. A highly experienced and talented shop team was assigned to manufacture the prototype. Later that year Air Force Secy. Brig.Gen. Cesar Ojeda, who originated the requirements for this "agricultural" transport (at once nicknamed "El Frutero"), resigned. His successor reduced its priority to minimum level. 3) basic wing and fuselage structure was assembled, and engines installed in early 1953. Later, engine ground testing showed overheating which was resolved by modifying the air inlets and installing a cooling fan on each drive shaft. It was a remarkable feat to design and build this large plane with so few people !

I left Argentina in December 1956 and no flights -perhaps only taxi tests- were made up to that point. I am almost sure work on the project was practically halted. Although the book Nurfluegel does not quote specific dates, it gives me the impression that flight testing may have commenced sometime during 1958, but definitely so in 1959. A former colleague in Cordoba wrote me one year later that the first official flight took place on 9 December 1960. According to Horten's book, at that occasion -or shortly thereafter-, the plane was introduced to then President Frondizi. Horten relates in his book that the air force test pilot was delighted by the handling and flying qualities. Shortly afterwards it was ordered to be demolished without given justification or reason (i.e. a la USAF vs Northrop -- what a strange repeat of history 12 years later in "downunder"! As a rule, authority burries its unwanted children: out of sight, out of public mind!)

At this point I would like to offer my own analysis of this bitter-sweet episode. As of 1953 the Peronista regime was shaken by several coup attempts, until its overthrow in 1955. The following administration grappled with too many political and budget problems, keeping it from concentrating on a systematic continuation with the previous aeronautical agenda. In this time period, two tailless delta wing designs (IA-37 and IA-48) were also being studied, but cancelled in 1959. One might conjecture that these contemporary and ambitious projects, each with their own proponents in the air force power structure, conflicted with each other to the point of cancellation - not too surprisingly.

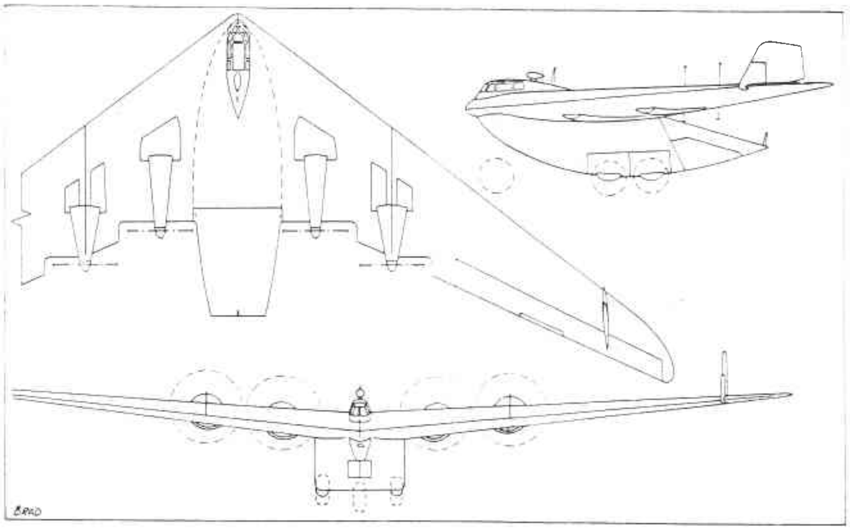
Now to the technical side. From Jane's I derived and tabulated the data below. Note that these figures indicate the IA-38's very efficient design. It was sized for four Indio engines. However, this engine was not made available, as all of them were needed for another airplane in production for the AAF. Instead, four Gauchos were installed in the prototype. No cargo aircraft available in the country at that time had the IA-38/Indio's payload capacity. Also note the high payload/grossweight ratio achieved by the efficient structure: thick wing of moderate aspect ratio and very short fuselage. This translates into the relatively low gross weight for the high payload. Refuel stop-overs could have been made as needed on the numerous excellent airfields and airports. Operating in this way permits low fuel- and high payloads (see table). I quickly checked the range and it was right on! The fuselage was huge: usable cargo floor length approx. 20', height 7' and width 10' ; 1400 cuft., dimensioned to hold not only crops but also animals, oil drums and other bulk. It probably could have been stretched had this become nececessary. The rough field, articulated, two-position and semi-retractable landing gear, loading ramp and engine installation were of ingenious, yet simple design. On page 208 of Dr.Horten's book, no range and payload are given; for the Gaucho engined prototype payload is zero and the take-off weight is the same as the empty weight given in Jane's! My explanation for this discrepancy is that the given weights correspond to the flight test condition. Another difference is in the Gaucho HP. Horten quotes 320, vs 450 in Jane's (also the official figure I remember). My explanation for this lies in the fact that the Gaucho was an oil-leaker under full power, and that Dr.Horten may have instructed testing to be done at 70% power - which is about minimum continuous. However, the calculated performance that could have been achieved, had the program continued, were evidently submitted by the AAF to Jane's! (Note: it is Jane's policy not to second guess performance data if it is not supplied by the manufacturer!) For comparison, the table also shows the corresponding design data for the british Bristol 170, a substantial number of which served with the AAF's Transport Command in military as well as civilian missions. As it turns out (coincidence, or purposely?) the Gaucho powered IA-38 had the same payload as the Bristol, and for very comparable wing loading,fuel fraction and range! Only the W/HP ratio is nearly twice the Bristol's, which points to take-off and climb problems, but could be partly offset by the slightly lower wing loading; this may be the reason why Horten off-loaded the prototype so that the take-off distance given in his book of 1540 ft. could be achieved. My conclusion is that a IA-38/Indio production would have made a magnificent compliment to the AAF's transport fleet.

HORTEN IA-38 KARL L. SANDERS 12/9/91

In retrospect, and despite the seemingly adverse decisions made three decades ago, all of the efforts left an invaluable experience that has been passed on -directly or indirectly- to a younger generation which has found partners for international joint ventures.

IA-38 / BRISTOL 170 COMPARISON. K.SANDERS 12/9/91

MODEL	FMA / Horten IA-38	FMA / Horten IA-38	BRISTOL 170 - MK.21 E
STATUS	prototype flown w/o. payload !	production planned	AAF std. cargo a/c. 1949 - 1960
ENGINES	(4) IA-16 GAUCHO	(4) IA-19 INDIO	(2) BRISTOL HERCULES 672
SOURCE	Jane's 58/59	Jane's 58/59	Jane's 51/52
(1) HP, TOTAL, RATED	1800	3000	3400
(2) WING AREA SQFT.	1431	1431	1487
(3) SPAN	105	105	108
ASPECT RATIO	7.70	7.70	7.84
LENGTH, OVERALL FT.	44.25	44.25	68.33
CARGO USABLE VOL. CUFT.	1400 approx.	1400 approx.	825
(4) TAKE-OFF WT. LBS.	35200	45100	40000
W/HP = (4)/(1) LB/HP	19.6	15.0	11.8
W/S = (4)/(2) PSF.	24.6	31.5	26.9
W/b = (4)/(3) PPF.	335.2	429.5	370.4
EMPTY WT.	18700	19800	27065
USEFUL LOAD + CREW	16500	25300	12935
% TO. WT.	46.88	56.10	32.34
CREW	2	2	3
PAYLOAD FOR RANGE (5)	12000	19534	11000
% TO. WT.	34.10	43.32	27.50
(5) FUEL FOR RANGE (6)	4500	5766	1935
% TO. WT.	12.78	12.78	4.84
STRUCTURE* +SYSTEMS+ PROPULS. WT. % TO. WT. *stressed for Indio	53.12	43.90	67.66
(6) RANGE, calc'd. ST.MI.	776 reserves?	776 reserves ?	190 with reserves !
AV.SPEC R.-(6)/(5) ST.MI/#FUEL	0.172	0.135	0.098
CRUISE SPEED, calc'd. MPH	134	152	164
TAKE-OFF DIST. / 50' FT. W=(4), CLto.=1.0 ; G.D.Hdbk.Chart	5000	5000	2310



The I.A. 38 tail-less Cargo Transport.

Ref. Jane's All The World's Aircraft 1958/59

THE I.A. 38.

TYPE.—Four-engined "tail-less" monoplane Cargo Transport.

WINGS.—Shoulder-wing swept monoplane. Special wing profile, 18% thickness at root and 10.4% at tip. Aspect ratio 7.7. Chord 6.4 m. (20 ft. 11¼ in.) at root, 1.6 m. (5 ft. 6 in.) at tip. Dihedral 5.7°. Incidence 9°. Sweepback at leading-edge 36.5°. All-duralumin two-spar semi-monocoque structure. All-metal Frise-type ailerons and split flaps. Total area of ailerons 4.5 m.² (48.4 sq. ft.). Gross wing area 133 m.² (1,431 sq. ft.).

FUSELAGE.—Incorporated in and below wing.

VERTICAL SURFACES.—No tail-unit. All-metal fins and balanced rudder near wing tips. Areas (each): fin 0.60 m.² (6.45 sq. ft.), rudder 2.80 m.² (30.1 sq. ft.).

LANDING GEAR.—Retractable nose-wheel type, all wheels retracting into lower part of fuselage. Hydraulic actuation. Oleo-pneumatic shock-absorbers. Dunlop wheels, tyres and brakes. Wheelbase 4.90 m. (16 ft.). Track 2.80 m. (9 ft. 2 in.).

POWER PLANT.—Four 450 h.p. I.A. 16 El Gaucho radial air-cooled engines mounted as pushers and driving Rotol fixed-pitch propellers. Provision has been made in the basic structure to instal four 750 h.p. I.A. 19 El Indio engines at a later date. Two fuel tanks (1,450 litres = 320 Imp. gallons each) in wings.

ACCOMMODATION.—Pilot's compartment for two over leading-edge of wing. Large compartment capable of accommodating 6 tons of cargo within and below wing. Rear loading door. Can be adapted for troop transport, etc.

DIMENSIONS.—
Span 32 m. (105 ft.).
Length 13.5 m. (44 ft. 3 in.).
Height 4.6 m. (15 ft.).

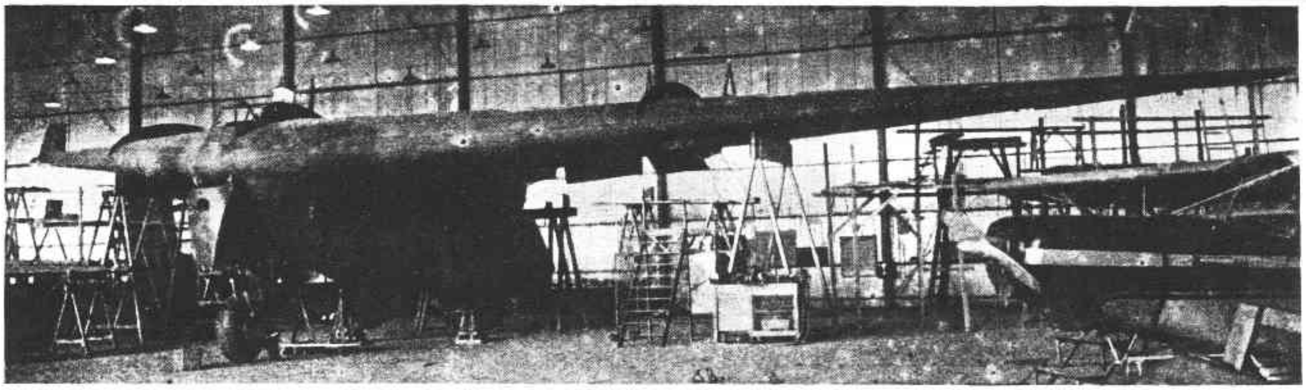
WEIGHTS (4 × 450 h.p. I.A. 16 engines).—
Weight empty 8,500 kg. (18,700 lb.).
Weight loaded 16,000 kg. (35,200 lb.).

WEIGHTS (4 × 750 h.p. I.A. 19 engines).—
Weight empty 9,000 kg. (19,800 lb.).
Weight loaded 20,500 kg. (45,100 lb.).

PERFORMANCE (4 × 450 h.p. I.A. 16 engines—estimated).—
Max. speed 252 km.h. (156.5 m.p.h.).
Cruising speed 215 km.h. (133.5 m.p.h.).
Landing speed 140 km.h. (87 m.p.h.).
Ceiling 4,500 m. (14,760 ft.).
Range and duration 1,250 km. (776 miles) or 5.6 hours.

PERFORMANCE (4 × 750 h.p. I.A. 19 engines—estimated).—
Max. speed 320 km.h. (200 m.p.h.).
Cruising speed 245 km.h. (152 m.p.h.).
Rate of climb at S.L. 168 m. min. (550 ft./min.).

I.A.—ARGENTINE REPUBLIC



The prototype I.A. 38 four-engined tail-less Cargo Transport under construction

LETTERS TO THE EDITOR

December 16, 1991

TWITT

Best wishes for the next season, but be advised that Spectra is not as advertised, modestly priced, but it is also a wax (Polyethylene) and as such, parts out rather well from the resin matrix. Hardly what one would want for a reinforcement. And so the manufacturers subject it to a treatment that essentially is a gas and electric charge torture at low pressure. Sounds a bit complex? It probably is, because it comes out with a price of about $45 a yard! (There may be some weaves that are less costly, but I did not investigate further. Back to aramide.) If one can stand the cost, the reinforcement evidently is the best, but I quit. (They doubtless will find a better way to get it to bond to resins or v.v., but I tire easily I guess.)

Meanwhile, enclosed is $15 for another year. I hope to submit an item soon, but have been set-back badly by an accident.

Best Wishes,
Syd Hall
Nevada City, CA

(Ed. Note: We are sorry to hear that you have had an accident slowing you down from your interesting projects. As the readers will see I have included the last page of Gene Sandburg's article on Spectra showing a comparison of strengths between different types of materials. It will be interesting to see is any of our other members try Spectra and have any difficulties, or find the price more than their building budgets will allow.)

December 12, 1991

TWITT

I was referred to you by Bill and Bunny Kuhlman (B_2). I am very interested in flying wings, and in building scale models of several of them.

I am looking for scale drawings of the Horten Ho I, Ho II, Ho III, Ho IV, and Ho VI sailplanes, the Ho IX/Go 229 jet fighter, and the Northrop XP-79B "Flying Ram." I know that Bill Young has drawings of the N9M-A, the Ho. IX, and the JB-1, and Henry Cherry has drawings of the Ho IC and Ho IV, but I haven't been able to find drawings of this Ho II, III, or VI.

Also, I am looking for a computer program that I can use to do the following: when data on a full-scale airfoil are entered, the program will modify the airfoil shape so that it will produce equivalent performance at a given scale in a model. This is particularly important for sailplanes such as the Ho IV and VI.

Lastly, I would like some information on your group and on your magazine. You sound like a most interesting organization.

Happy Holidays,
Jason Wentworth
3081 N.W. 4th Terrace
Miami, FL 33125

(Ed. Note: We will be sending Jason an information package so he can see about joining TWITT. But in the mean time, if anyone out there can help him with information about the aircraft he has specified, I am sure he would be most appreciative.)

August 26, 1991

TWITT

Please find here enclosed some pictures of the PUL 9 tailless powered plane built by Nike Aeronautica (Via Ferrarese 10, 40013 Castelmaggiore, BO, Italy, tel and fax 051-765714).

This tailless has been designed by Dr. Reimar Horten, now living in Argentina, for Mr. Siegfried Panek. Hence the designation PUL= Panek Ultra Light.

Mr. Panek has learned to fly on the PUL 9, without double control system.

The PUL 9 single seater has been extensively flight tested by Nike Aeronautica, confirming the good performances already obtained in Argentina with the prototype.

An improved two seater (side by side) version, designated PUL 10, is under construction: it features fully retractable landing gear.

Assembly rigs are being prepared for both models, which will be marketed by Nike Aeronautica. Vital specifications of both types are attached to this letter.

The PUL 9 is the first tailless plane being built in Italy since several decades.

I am enclosing also a photocopy of the column I ran in the Italian magazine MODELLISTICA, in which I mentioned TWITT Newsletter: let's hope that some Italian tailless fan will accept my invitation to join TWITT.

Regards,
Ferdi Gale'

(Ed. Note: I apologize for this getting into the newsletter so late, but it accidently got buried in the pile of material on my desk devoted to TWITT. A past newsletter noted that your article did spur some interest in Italy, since we have at least one new member from your beautiful country. The one side view aerial shot and the specifications are presented on this page. Thanks for this interesting information.)

SPECIFICATIONS

	PUL 9	PUL 10
Span	9 m	10 m
Empty Wt.	150 kg	190 kg
Min Speed	55 Km/h	60 Km/h
Max Speed	225 Km/h	300 Km/h
Engine/Pwr	Rotax 447/42	Rotax 532 or Rotax 912/80
T.O. Run	250'	300'
Land Run	300'	350'
Seats	1	2

AVAILABLE PLANS/REFERENCE MATERIAL

Tailless Aircraft Bibliography
by Serge Krauss
Cost: $20
Order from: Serge Krauss
3114 Edgehill Road
Cleveland Hts., OH 44118

Horten H1c construction drawings with full size airfoil layout. 30 sheets 24" x 36" with specification manual. Price: $115.

Horten Newsletter
Cost: $5 per year for US/$7.50 foreign
Order from:
Flight Engineering and Developments
2453 Liberty Church Road
Temple, GA 30179
(404) 562-3512

FLYING WING SAILPLANE PLANS AND KITS: Two time-proven, 13m homebuilt designs suitable for the novice pilot. Build either the MONARCH "F" ULTRALIGHT (19 to 1), or the PIONEER II-D (35 to 1) sailplane.

Info packs $8 each, or $15 for both.

Marske Aircraft Corp.
130 Crestwood Drive
Michigan City, IN 46360

PUL 9 IN FLIGHT

Dedicated To
J.K. "JACK" NORTHROP

Silver Anniversary

1991
25TH ANNUAL
NORTHROP FLYING WING CONTEST
FLOWN AT
UNITED STATES SAM CHAMPIONSHIPS
JEAN, NEVADA

Sponsored By
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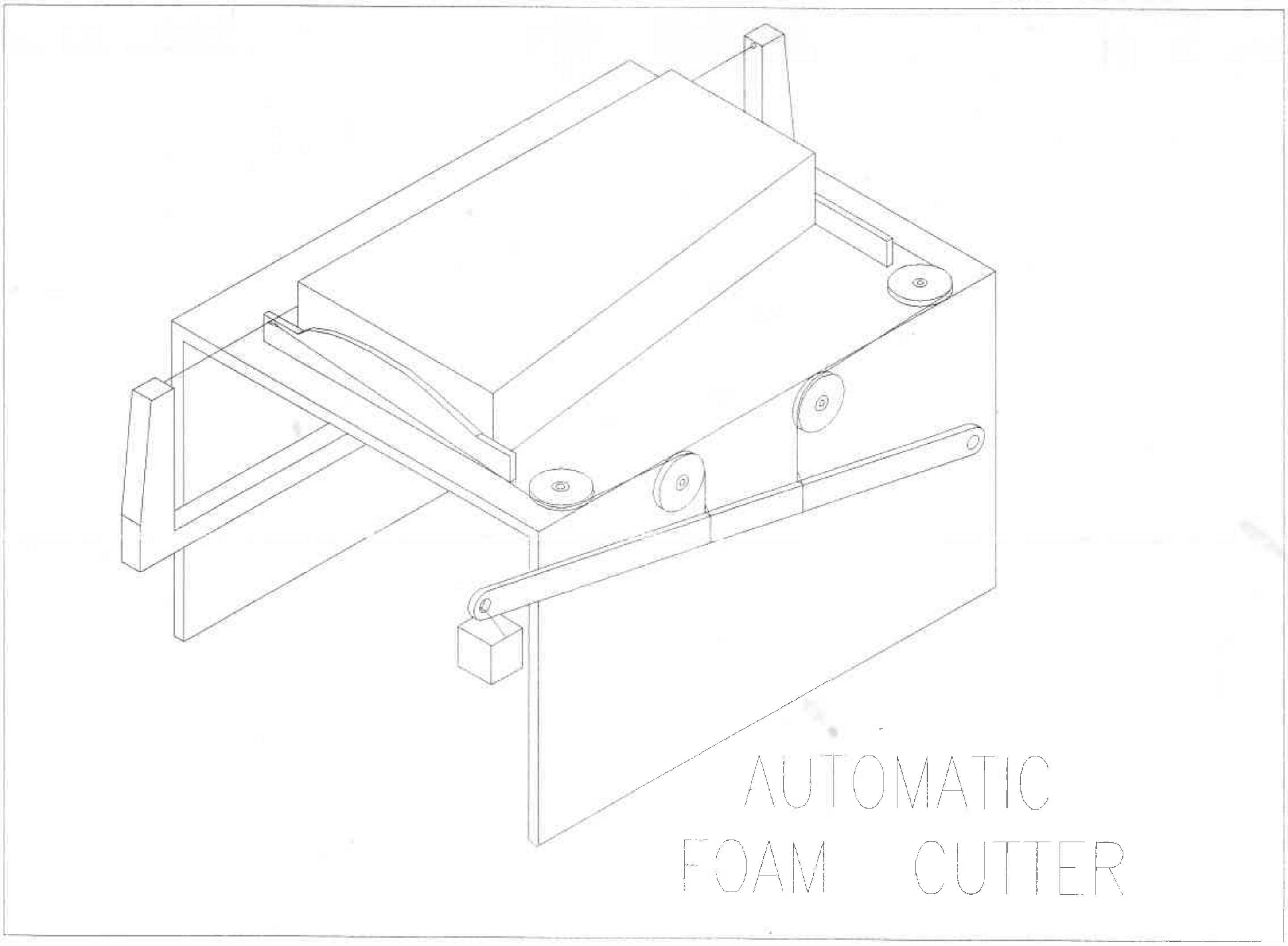


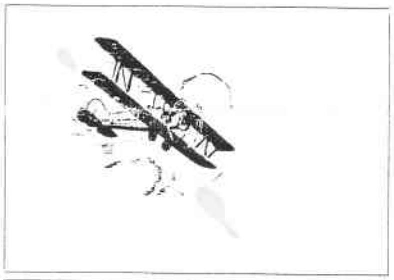
Automatic Hot Wire Foam Cutting Machine

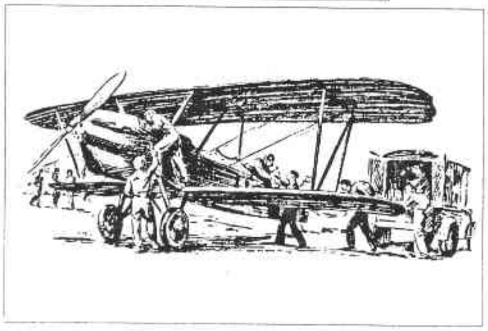
The Auto-Foam Cutter is shown in the schematic drawing above It shows a tapered wing section about to be cut. The advantage of the device is that the resulting section has an extremely smooth finish requiring very little sanding and filling. This saves many hours of work, dollars, and pounds off of the finished aircraft.

The foam cutter works like this. The templates are fastened to the ends of the foam block. They are made with ramps (extensions) ahead of and behind the required contour. These are for the wire to rest on and be guided to the start of the cut and support the wire after the cut. The templates work best if they are made of metal and insulated from the foam by a space. The foam is weighted down during the cutting to hold it flat and in place.

The wire is pulled through the foam by means of a weighted lever arm (see the above diagram). A wire hook is attached to the hot wire outboard and just adjacent to each of the two templates. Dacron fishing line is tied to the hooks, threaded around the pulleys and attached to their appropriate places on the lever arm. The distance the line is pulled during the inscribed arch of the lever arm, at the line attach point, must equal the length of the template. Dacron fishing line is used to minimize the line stretch to insure an even cut. To obtain the best cut use the minimum allowable heat on the wire and the minimum allowable weight on the lever arm. This provides a slow smooth cut.

Gene Sandburg





STRENGTH OF MATERIALS COMPARISON CHART

ENGINEERING PROPERTIES	ALUMINUM 2024 T351	ALUMINUM 7075 T651	SITKA SPRUCE	DOUGLAS FIR	E GLASS	GRAPHITE (Carbon)	KEVLAR * (Aramid)	SPECTRA ** 900 PT (Polyethylene)	SPECTRA ** 1000 PT (Polyethylene)
Tensile Strength YIELD	42,000	67,000	D.N.A.	D.N.A.	D.N.A.	D.N.A.	D.N.A.	D.N.A.	D.N.A.
Tensile Strength ULTIMATE	64,000	76,000	350 / 370	300 / 400	128,000 / 20,000	211,000 / 100,000	420,000 / 125,000	98,000+/- 15,000	129,000+/- 8,000
COMPRESSION Strength	65,000	77,000	2,670 / 5,610	3,780 / 7,240	62,000 / 20,000	204,000 / 90,000	30,000	8,600+/- 200	10,000+/- 200
Modulous of ELASTICITY	10.6×10^6	10.4×10^6	$1.23/1.57 \times 10^6$	$1.56/1.95 \times 10^6$	5.5×10^3	12×10^6	?	$4.3(+/-.2) \times 10^6$	$5.5(+/-.2) \times 10^6$
Laminate test Thickness	D.N.A	D.N.A.	D.N.A.	D.N.A.	0.016 in	0.012 in	?	0.019 in	0.026 in
DENSITY (water=1.0)	2.75	2.78	0.37 / 0.40	0.45 / 0.48	2.55	1.75	1.44	0.97	0.97

The above chart is designed for the comparison of some of the materials we use in our homebuilt aircraft today. The mechanical properties of aluminum are taken directly out of Ryerson's handbook. Aluminum is manufactured to rigid specifications so these numbers can be used for design purposes. The mechanical properties of wood are taken from data published by The Forest Products Laboratory. The two numbers represent the range that they encountered when running the tests. The data on the various composite fibers also are represented by two figures. The larger number represents the data supplied by the fiber manufacturer, the smaller number represents numbers recommended by various homebuilt aircraft designers (The exception to this is the Spectra data, all of that information is from Allied Signal). They are not to be used as gospal as the builder is the materials manufacturer. The designer / builder should make up sample coupons of the materials in the same manner that will be used in the construction of the aircraft. The coupons should then be tested. The data from the test results should be used in calculating the structure. A test structure should then be built and tested to distruction to verify the material and design concept.

I'll give you an example of what I mean. Byron Stender, a gaduate of Darmstadt, and one of the design team of the D-24, designed and built the first nonresearch fibre glass aircraft (a sailplane) the BS-1. He built and flew it to first place in the German Nationals. After nine days of the ten day event he had accumulated enough points to win it without even flying the last day. He built three BS-1's. A few years later, while doing a high speed timing run, it came apart and Byron Stender died in the resulting crash. The remaining structure was tested and found to be only 25% as strong as Byron had calculated. A word to the wise!

Under E Glass you will find 20 ksi for both tensile and ultimate. This isn't a misprint. This is what George Appleby, designer of the Zuni, recommends. One reason for this is probably the low Modulous of elasticity of fiber glass. You need to use an excessive amount of glass for rigidity.

There are a lot of different numbers used for the tensile strength for Graphite. George Appleby, says to use 100 ksi, Alex Strojnik, 125 ksi, Martin Hollmann, 130 ksi, and Hans Neubert, 160 ksi. Irv Culver uses 90 ksi in compression because of Carbon's low buckling strength. He also advocates square cross sections for spar caps, for the same reason.

Kevlar, although about as strong as carbon and lighter, has only 30 ksi Compression Strength. Consequently it should not be used for an upper spar cap or other structure requiring Compression Strength.

Spectra, the new kid on the block, has some interesting possibilities because it is so light. It even floats on water. Spectra is generally in the same category as Aramid. Even though it has a somewhat lower Compression Strength, in other respects it goes from nearly equal to far exceeding the Aramid's properties. It is strong in tensile, extremely tough, light in weight, punchure resistant, abrasion resistant, damps out noise and vibration,and last but not least, it is more economical to use. If you like, you can even lay it up around the cockpit and make it bullet proof.

Gene Sandburg, Modesto, CA 8-1-91

* Kevlar is the Registered Trademark of Dupont. The basic information is taken from their H-05500 information booklet.
** Spectra is the Registered Trademark of Allied Fibers. The above information is taken from their "SPECTRA High Performance Fibers for Reinforced Composites".