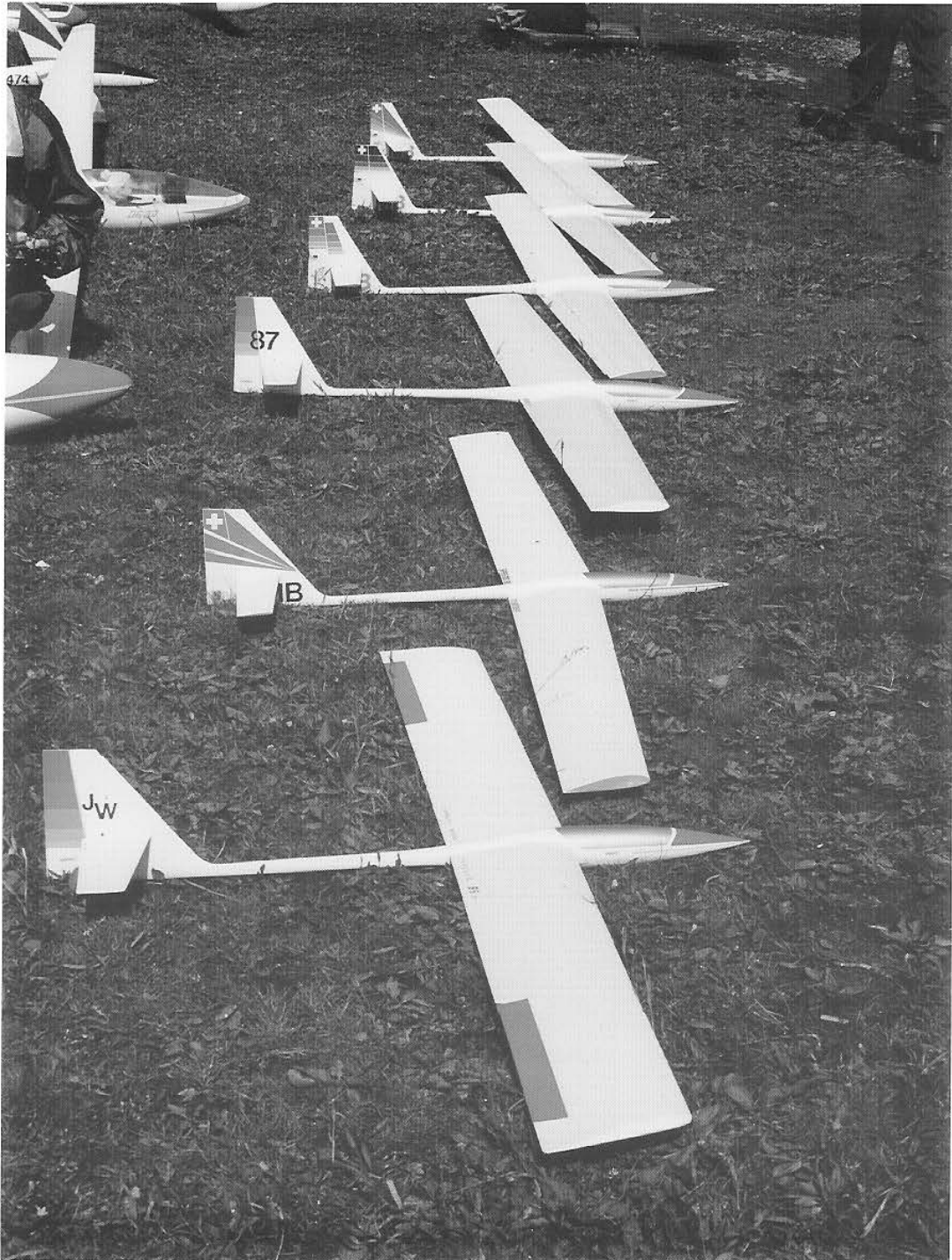


SOARTECH



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EDITOR'S INTRODUCTION

This issue is being published in a very busy time for us. We have been asked to supply and support the late David Fraser's "Sailplane Design" performance program, and "Airfoils at Low Speed" data disk. We have also undertaken distribution of Hans-Walter Bender's fantastic airfoil collection data disks. Add to this a project to translate and make available two computer programs from Ludwig Wiechers to view, modify and plot this extensive collection of over two thousand different airfoils. One of the programs works with Windows and the other with DOS.

SoarTech 11 and Other Books in Work

Meanwhile, the collection I'm now distributing consists of the airfoil plotting coordinates in ASCII text files that can be recognized and manipulated by any computer. Hans-Walter Bender and I are going to work to turn this complete collection into a book with the idea that not all of the people who might want such a collection are able to use computers.

I am also committed to work with Charles Lindsay to produce a model soaring version of his book "Handbook of Soaring Meteorology". Will there be a SoarTech 11? The answer is definitely yes, but it will be quite a while before I can go to work on it. For this reason, I will not be taking advance orders for the next issue. I'll see that it is publicized and that those who have purchased SoarTech previously are notified when it is published. You may also want to keep your eyes open for announcements of the availability of these programs and other publications which will be published and distributed by SoarTech.

Programs in This Issue

SoarTech 10 has several articles that explain the analysis of model sailplane design and flight by using computer programs to do the calculations. Initially, I wasn't going to include the listings of the programs themselves, but after thinking about it, I decided that the listings are extremely valuable, because they document all of the calculations and processes necessary to do the analysis. They also contain very valuable modules that relate to input and display of data as well as output of results. A program writer is often challenged more by input, display, and output than by the calculations that produce the answers. There are literally hundreds of valuable insights available to the individual who studies these different approaches to computer analysis.

For folks who'd like to make use of these programs, I'm making all of them available on a single disk. If you'd like to receive them, Send \$12 to cover the cost of the disk, packaging, postage, and wear and tear on the equipment and I'll send you a copy. (\$14 for orders from outside the North American Continent.)

This isn't any kind of a regular software offer, so there is no manual or detailed instructions on the use of the programs other than the articles in SoarTech 10. It is just a time saver for folks who'd like to use the programs by sparing them the time it would take to type in the code. Ask for the SoarTech 10 disk.

THE ARTICLES IN SOARTECH 10

Molded Sailplane Construction: Martin Bamert isn't the first person to make molded sailplanes, but I've never seen anyone who has documented each step with the appreciation for detail that he has provided. Every piece of the aircraft and every step in the construction of these beautiful models is detailed in the photos and explained in the text and captions. You may never undertake the construction of a model like this, but in this material there are dozens of ideas and illustrations for anyone who builds and flies RC sailplanes. If Martin's accomplishments also stimulate you to build molded composite models, all the better. And, if you can't appreciate the models, check the scenery!

Vision and Soaring: I've repeatedly discussed some of the material in this article in my monthly "Flying Models" RC Soaring column. When I've received responses to those columns, people have inevitably said that when they got the right lenses, it was a "breakthrough" experience for them. I've also been told many times that the optometrist was very hard to convince that doing his "standard stuff" doesn't solve the problem. Perfect vision goes near-sighted when looking into a blank sky; and many a sailplane has been lost !

Book Review: "Airplane Performance Stability and Control" by Perkins and Hage has been the textbook since before I went to college almost 40 years ago. It was originally published in 1949. Max has been looking for an up-to-date replacement for this old standard. In "Engineering Analysis of Flight Vehicles" by Holt Ashley, he has found *some* of what he was looking for. Like Perkins and Hage, it is an engineering college level text book with all of the formulas and equations that apply to the subject, but with some of the theory modernized. It incorporates numerical methods of analysis, suitable for computer applications, and other innovations that reflect later developments in the field. It is not a book for the "Casual Reader".

The Selig 4233 Airfoil: Until the publication of "Airfoils at Low Speed" by Selig, Donovan, and Fraser (SoarTech 8), it was difficult to do comparative analysis of different sailplane designs. Now that we have this incomparable tool, Oliver Wilson has been doing what it was intended for. He has been using engineering methods to analyze his ideas about sailplane design. There has actually been little of this sort of in-depth analysis published since SoarTech 8 became available. Oliver's ideas may not be the last word on the subject, but he shows how to use this material in a way that is available to any model builder/designer regardless of his technical background.

Symmetrical Airfoils: Jef Raskin loves to fly sailplane acrobatics on the slope. He has also invested a lot of study, thought, building and flying in that part of our sport. If you want a sailplane to fly in a wide range of slope soaring conditions, it must have an efficient wing. Most powered aerobatic aircraft designers are little concerned with airfoil development, but for soaring, the airfoil can be the main determinant of the aircraft's performance. *OK airfoil designers; why can't we have symmetrical airfoils that are as effective as cambered sections?* With camber control and the things we've learned since Selig, Donovan, and Fraser began their work, why must we assume that symmetrical is less efficient? We certainly know that high lift coefficient alone is not the key to performance. We also know that low drag can be equally important. Let's go to work on it and come up with some symmetrical airfoils that will soar with the eagles!

Martin Simons: Our perennial guru has looked again at the world after "Airfoils at Low Speed". When he wrote the paper, that we published in SoarTech 9, on the subject of the use of wind tunnel data in model design; the work of Selig, Donovan, and Fraser had not begun. Martin revisits this area now in light of this wealth of new information.

Mathematical analysis of Winch Launching: The ISF (International RC-Soaring-Flight Forum - in Swiss-German it's correct title is "Internationales RC-Segelflug Forum") was started over ten years ago by (I believe) Hans Ruedi Schläpfer, but it has been organized and chaired for many years by Rolf Girsberger (the developer of the RG airfoils). We have published ISF papers in SoarTech several times, and this is from the proceedings of the seminar that was held in December of 1991 at Baden in Switzerland. Several people, that I'm aware of, have worked on the problem of analyzing the winch launch to optimize its efficiency. In this paper the authors have provided not only their analytical concepts, but have actually given us the algorithms we need to develop their analysis further and to carry it to our own conclusions.

Wing Loads and Wing Strength: So far this is an area that has not been well represented in SoarTech. With these two programs, Steve Pituch has given us two engineering tools that can be used to analyze the flight loads on a sailplane's wing, and then design in the structure to carry them. Like the other programs in this issue, the complete source code is provided so that they can be modified, expanded, extracted, or just used as they are.

Downwash and Wing Loads: These two very brief papers by Max Chernoff provide both the mathematical background and simple computer programs to use them. Downwash is often neglected in stability and trim computations, yet it plays a critical part in both stability and control analysis. Run your favorite model through these calculations and see how the lift on the wing changes the flow over the tail. It is eye opening if you've never looked at it before.

Max gave us an earlier version of the paper on wing load distribution in SoarTech 9. He later became dissatisfied with that analysis and now has offered this more extensive and accurate update. Along with it is a new program that does the calculations.

Flying Wings: I've always felt that the swept flying wing was the only form that offered an opportunity for really high performance. The "Planks" are easier to design and build, but I never felt that they were efficient. Now, Denis Oglesby has offered us the results of his extensive analysis; providing a new concept that he feels does offer high performance potential. Will it do all that he expects? The answer isn't in yet, but this is an exciting concept. Who will be first to find if it lives up to its promise?

The airfoil ordinates I've supplied for the Eppler 182 and the modified Eppler 186 were printed using one of the many output options available from Ludwig Wiechers' "Profiles für Windows" which I mentioned earlier. This is a very powerful program for accessing, viewing, modifying and plotting all of the airfoils in the Bender collection. As you can see this is from the initial test version of the English edition. Let me know if you are interested in these programs.

Well that's it for this issue. Has RC soaring reached the limit of its performance potential? Will all future sailplanes models gradually grow to look and fly exactly alike? Will we stop looking for new and better ways to soar?

Not Likely! - Herk

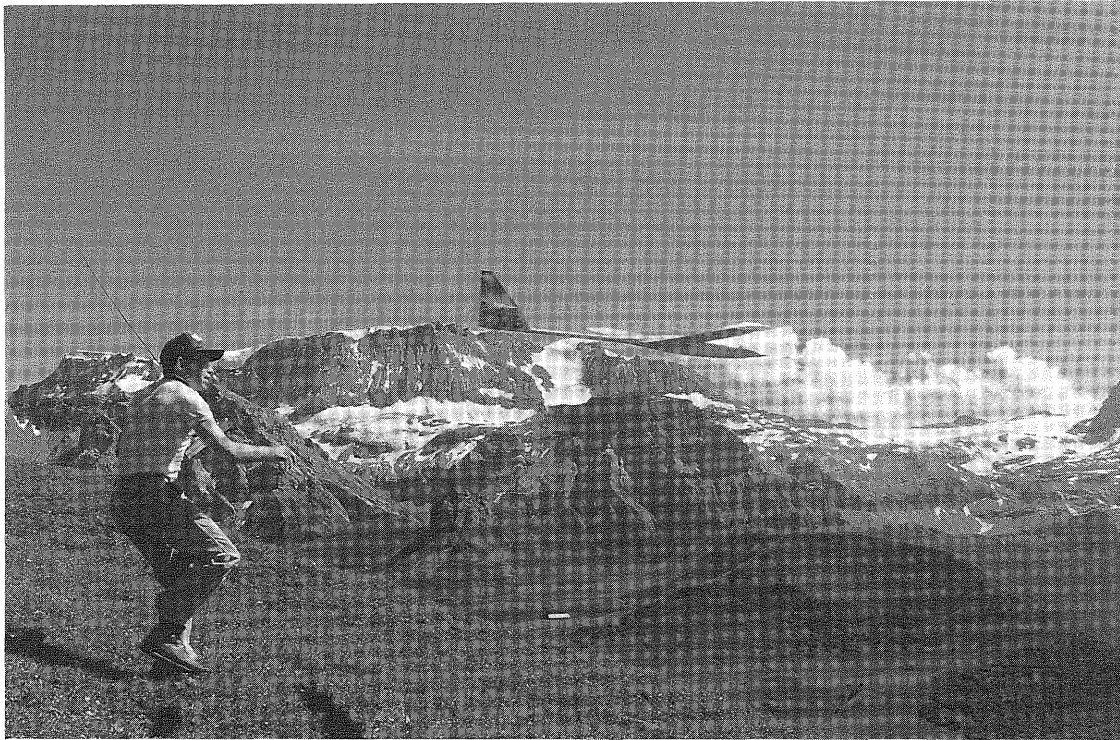
SOARTECH JOURNAL #10

"SoarTech" began about fourteen years ago as a series of technical papers in the Tidewater Model Soaring Society newsletter which we called the TMSS Technical Journal. With encouragement and ideas from Jim Gray and Bruce Abell, it grew into what is now the "SoarTech" Journal. It is an English language technical forum for Radio Control Soaring; containing papers submitted by interested modelers, and from other publications.

SoarTech is intended to provide a vehicle for the publication of information and data which is too lengthy or too technical for publication in the popular press. SoarTech is edited and published by H. A. (Herk) Stokely, and sales are by direct mail from him, c/o SoarTech, 1504 N. Horseshoe Circle, Virginia Beach, Virginia 23451 U.S.A. Since the journals are produced at irregular intervals, no subscription as such is possible. With each issue information about future publications is provided, and new issues are announced in the model press.

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Take - off at Lavey ridge: Martin launches into a huge bowl which, at times provides extremely strong thermals. Using these thermals you can almost disappear into the blue yonder. Acquired height can then be translated into breath-taking speed runs approaching the 200 miles per hour limit. A very efficient aerodynamic design as well as the thinner air at these altitudes make such speed runs possible.

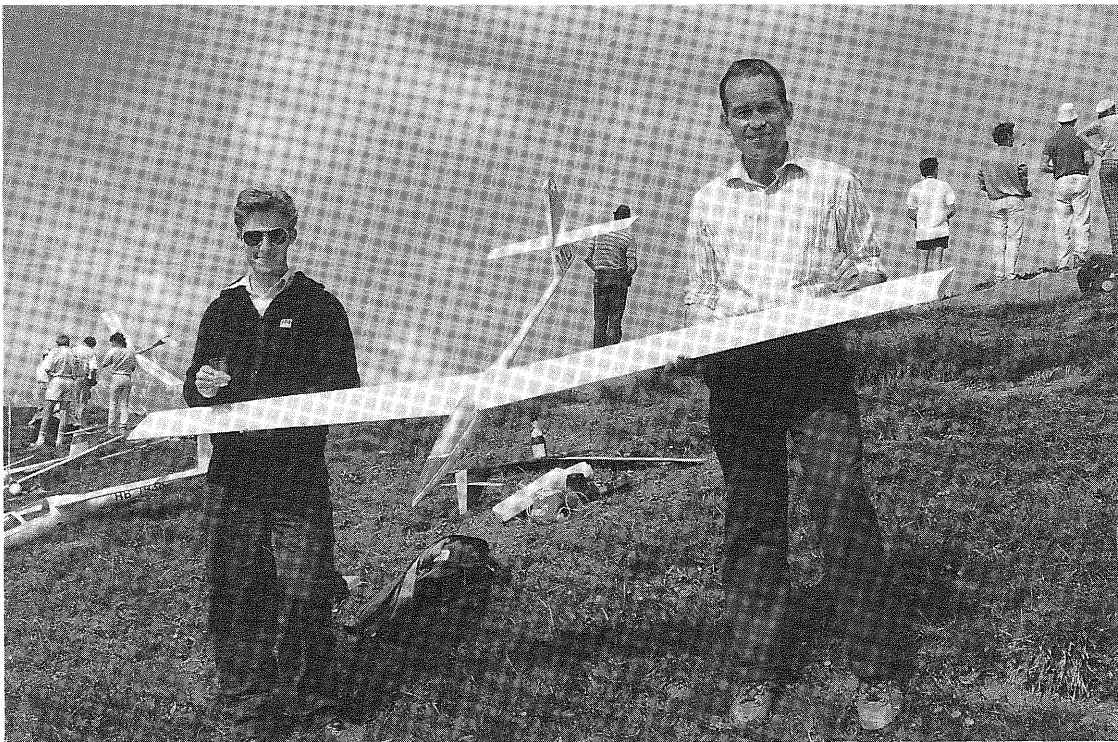
Flying in this alpine environment adds challenges pilots normally don't face when flying in more flat surroundings. For instance, a thermal can be so strong that your model easlily flips over when flying into it. Due to these thermals, the air is much more turbulent requiring better piloting skills. Landing, because of the unique topography, poses the greatest challenge. With sometimes strong turbulence close to the ground, best landings are achieved by approaching the landing spot well below eye level and at an increased speed; then pulling your model up parallel up the hillside. Excessive speed and height are controlled with the spoilers and the model is landed smoothly uphill.

MOLDED SAILPLANES

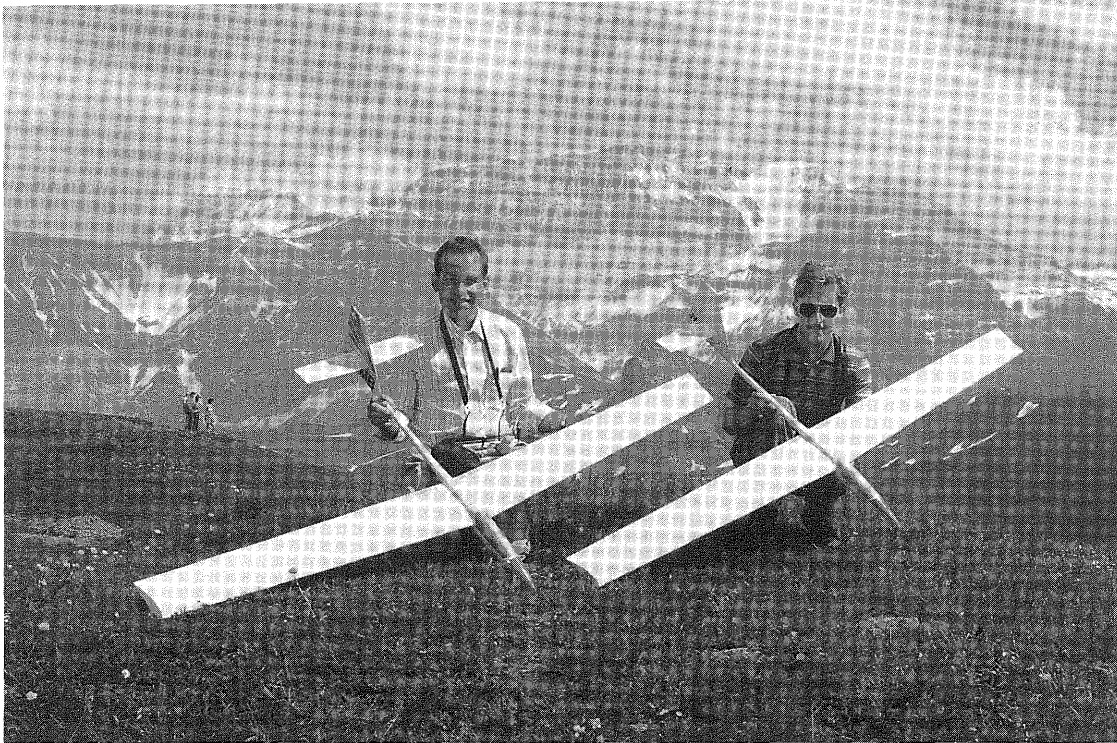
Molded sailplanes are the ultimate in both full scale and model construction. They offer the promise of the highest levels of performance, quality, accuracy and reproducibility possible. Because of the work involved, they do require a tremendous commitment to a given design. As you will see in the following pages, this kind of construction is quite complex and involves many man-hours of preparation at each stage.

Once the molds are constructed, modification of the design is also quite difficult. However, when the design is good, and the structural elements are right, production of models like these offer perhaps the greatest modeling satisfactions possible. You may never aspire to produce models by this process, but on each page there are ideas and applications that are usable by anyone on almost any projects. I think that one picture can communicate a concept as effectively as several pages of text. If I am correct, this following article is an encyclopedia of model sailplane design and construction.

Even if a person doesn't want to build molded sailplanes, there are a wealth of ideas and information to be gained from studying this material. It also spends a few pages showing that the rewards can be very great - both in terms of beauty and performance.



After a successful maiden flight, Jürg Wermuth (left) and Martin Bamert are enjoying a glass of sparkling wine.



Martin Bamert with his friend Jürg Wermuth at one of their beautiful flying sites in Switzerland.

ALL MOLDED F/G SAILPLANE CONSTRUCTION

by Martin Bamert

Introduction - by Byron Blakeslee. This report is an expanded version of the article Martin wrote for my R/C Soaring column in the September, 1988 issue of Model Aviation magazine. That column contained just six of the more than 40 photographs Martin took of his molding process. It really couldn't do justice photo wise at least, to all the work that was expended in Martin's pursuit of the "perfect glider". Therefore, we concluded that Soartech was the ideal forum to show the "whole story".

Martin is a Swiss citizen, raised in the capital city of Bern and now permanently living in southern New Jersey. He was on temporary assignment in Sacramento, California when he wrote the original article. When the September 1988 MA came out and Sailplaners read about the two Speedos, there were, shall we say, "raised eyebrows", After all, here was a guy talking about diving a glider 800 feet and going 150 MPH! Surely, that sort of thing is just not possible. It probably isn't at most slope sites, but Martin was talking about flying a very strong and sleek little ship from mountain tops in the Swiss Alps. Those who saw Martin fly his Speedo '87 in California the summer of 1988 were left with no doubts about what the plane could do.

At the MARCS Symposium in November, 1988, the Saturday evening post banquet entertainment was a very interesting slide show by Steve Metz of the Minnesota R/C Soaring Society. Steve had attended several full size and model glider events in Europe that summer and took many excellent slides. one of his stops was at the Hahnenmoospass, high in the Swiss Alps. There Steve met Jürg Wermuth, Martin's partner in the Speedo project, and saw Jürg fly his Speedo '87. Steve said Jürg was doing such incredible things with the plane that all the other pilots would bring their ships down when Jürg flew so they could watch! This says a lot because many of the top flyers in Europe come to Hahnenmoospass in early August for a great mountain flying get-together. Dan Pruss wrote an article about the 1983 meeting, which appeared in the May, 1984 issue of Model Aviation.

Now, on to Martin's description:

In this report I am going to talk about two gliders: the Speedo '84 and Speedo '87. The Speedo '84 was designed by Jürg Wermuth, a friend of mine from Switzerland. This twist-wing design with a 78 inch span aroused my curiosity because of its exceptional flight performance. "Twist-wing" means both wings rotate slightly about the joiner rod for roll control instead of using ailerons. In early 1985, Jürg sold me two fuselages, and with his valuable hints, I built two of these models. Building a model like that is not exactly an easy task. Because of its small size (78 inch span), the whole model has to be built very accurately in order for it to achieve an acceptable level of performance. The glass fuselage (without white gel coat) was

reinforced with plenty of carbon fiber and kevlar. The wing was built in foam/glass and sheeted with obechi wood. The glass cloth was laid diagonally over the foam cores for increased torsional strength (very important for high speed flights!). It uses a JW airfoil (designed by Jürg), which is 10% thick and slightly under cambered approaching the trailing edge. The rudder, as well as the stabilizers, was sanded out of a piece of balsa wood. Stab airfoil is roughly a NACA 0006, fully symmetrical. Wing, stabs and rudder were covered with a white polyester iron-on film and give the model its final finish. RC controls are twist-wings, elevator and rudder. Building in the controls created some problems because space was very limited in the fuselage. Even though I love working with tweezers, I was finally happy to have completed installing the three servos, receiver and batteries.

The first flights overwhelmed my expectations. It flew in a slight upwind when even the lightest gliders were fighting to stay in the air. With a wing loading of 15.1 oz/sq ft, that is quite an accomplishment. The model also responded very well to thermals and easily climbed to heights where you have trouble recognizing it. The Speedo '84 is completely aerobatic and is in its element when diving 600 to 800 feet straight down. Nothing rattles or shakes and it behaves stably and predictably during high speed dives. By pulling up into a zooming climb, most of the kinetic energy can then be converted back into height. The model has been clocked at over 100 MPH. I have flown my Speedo '84 over 200 hours and never crashed it. Every slope I go to it attracts curious and inquisitive model pilots.

Surprised by its great overall flight performance, Jürg and I decided to join forces and design the Speedo '87. The main reasons for the new design were to increase the size (so many times it became a problem to recognize the correct position when flying far away), to improve minor imperfections in the design and to utilize a more modern and accurate building technology. This could only be accomplished by employing molding technology using epoxy resins, glass, carbon and Kevlar fibers.

The Speedo '87 is roughly 25% larger, with ample space in the fuselage, a cleaner (more flush) wing to fuselage transition and molded fiberglass (glass-balsa-glass) sandwich wing and stabilizer sections. Because building molds is a very time consuming process, Jürg made the fuselage mold and I made the molds for the wings, stabs and special levers and parts. Airfoil used is the RG 12A - 1.8/9.0 (1.8% camber; 9.0% thick), an F3B airfoil designed by Rolf Girsberger, a Swiss model pilot and F3B enthusiast. The stabs again used the NACA 0006 airfoil.

In order to make the wing molds, I first had to build a positive form - or master wing. This I did by covering foam cores with prefabricated fiberglass skins. The skins were epoxied to the cores and clamped between two very accurate and straight wooden blocks. The blocks are about 15 cm thick, 42 cm wide and 150 cm long and are made by side gluing 2.5 cm thick boards together to

form "butcher blocks". They were surface planed several times on both sides in a carpentry shop to obtain flatness. An obechi leading edge was added and sanded to shape. At eight equi-spaced stations, I made airfoil templates to verify the accuracy of the wing. The wings were sprayed with a gray polyester auto body surfacing material and sanded to eliminate imperfections. This process has to be repeated until the wing was perfect in surface finish and airfoil shape. In my case, I had to go through the process three times.

Once the master wings existed, making the molds could proceed. It took place on the same wooden blocks the master wings were pressed between. After waxing and polishing to prevent the molding material from sticking, one master wing was fitted within the aluminum frame pieces as shown in Drawing #1. The frame and anodized aluminum L.E. piece are well waxed also, but not polished, to prevent sticking.

The first actual molding step is to cover the wing top with a gray molding resin. There are many molding resins on the market. The one I bought in Switzerland (RG-Formenharz mit Harter F-15) would probably not be available in the U.S., but equal substitutes should be easy to find. A second coat of molding resin is applied to make sure the wing surface is completely covered and to obtain a thickness of approximately 1 mm. While the second coat of molding resin is still wet, a thin layer of 30 gm/sq meter bi-directional glass cloth is added. This is to strengthen the resin layer and to prevent any sand grains from being pushed through the molding resin, destroying the surface of the mold. A third coat of resin on top of the glass finishes the resin "shell". Then a mixture of one part resin to ten parts of quartz sand (mechanically very stable material - plus two steel tubes) is poured in up to the top of the frame. The tubes add strength, plus are used when separating the mold halves as we shall see later.

Once the lower half (wing's top surface) of the mold is made, the upper half can be built in the same way - right on top of the lower part. This is done by placing the lower half in the aluminum frame with the sand surface against the wood block. As before, the lower surface of the wing as well as the flat area in front of the leading edge must be adequately waxed and polished to prevent sticking. The frame is waxed but not polished. Positioning pins (see Drawing #2) should be installed before starting the molding resin step. This whole process is done twice, once for each wing. The molds for each wing weigh about 120 pounds.

The finished molds are waxed and polished several times and then treated with a PVA (Poly Vinyl Alcohol) separating agent, which leaves a thin transparent film after drying. It is imperative to use a PVA separating agent when a white gel coat is to be used to prevent the aggressive polyester gel coat from sticking to the mold and consequently damaging the wing being built. Now the white polyester based gel coat is sprayed into the molds. On top

of that, 40 gm/sq meter glass cloth is added and soaked with epoxy resin. Here again, there are literally hundreds of suitable epoxy resins. The one I used has a working time of about 50 minutes at 20 degrees C. and has a low viscosity (very thin). It is called "Epoxyd-Laminierharz TypLF". This resin is approved by the German FAA to build full scale aircraft. Then a 1/16 balsa wood (medium to light weight) skin is put on top of the soaked glass cloth. This setup is placed in a polyethylene bag, sealed and put under vacuum for 24 hours.

After removing from the bag, 120 gm/sq m glass cloth plus reinforcements are put on top of the balsa. The spars are glued on top of the lower sandwich of the wing. The sub spars are cut from blue foam while the main spars consist of plywood and carbon fibers. For more information refer to Drawing #3. Each builder will of course have to determine optimum spar sizes to suit his wing design. Behind the main spars is a place for additional ballast weights. The Speedo '87 main spar is pretty involved because the thickness of the airfoil at the root is only 20 mm and dihedral is built into the wing (total dihedral is 5 degrees).

At this stage all the edges are carefully trimmed with a sharp knife, making sure the wing halves will mate together properly. The wing halves are glued together using epoxy resin with the molds securely clamped together. The wing halves can't be sanded prior to gluing as this could damage the mating surfaces of the molds. During this gluing step the molds are left leading edge, downward so the epoxy flows and forms a nice fillet inside. The epoxy gluing the trailing edge is made thicker so it won't run downward. our molds are designed to make wings up to 2.63 meters span. We just cut the ends off to make the required size. Having no molded wingtips allows us to experiment with different tip shapes in the future. I would like very much to provide wing samples with this book so that you can see what kind of leading and trailing edge, as well as surface quality can be achieved by using this technology.

The positive, or master form for the stabilators was done in a different way than the wings. In order to achieve greater accuracy at the leading and trailing edges, the "spatula technique" was used. It is a much more involved way of building an original, but in return gives you the greatest possible accuracy. All the current high-tech F3B gliders are made this way. This method starts with a very sturdy aluminum base plate the exact length of the stab or wing to be made. On each end of the plate is screwed an airfoil template, with exactly half the airfoil showing above the plate. The space between the root and tip airfoil halves and the base plate is then filled with gray molding resin of the same type as used for the wing. The resin must be close to zero shrinkage (although I have not found any mention in the specs). It is also "thixotropic", which means "not flowing away" as any other resin would. These properties are especially important for the resin used in the spatula technique.

With a very straight rule, the resin is dispersed within the given space. Starting at the trailing edge, the rule is pulled forward toward the leading edge. This drawing process is repeated up to twenty times and the amount of resin scraped off decreases each time. The root and tip templates are removed after the resin is cured and an aluminum frame is built around the base plate. From here on the molding process is pretty much the same as for the wings. Since the stabs are symmetrical, I had to build only an upper and lower section of one part. Building and actual stab is done very much in the fashion as the wing except the balsa wood used for the sandwich is 1/32 in. thick.

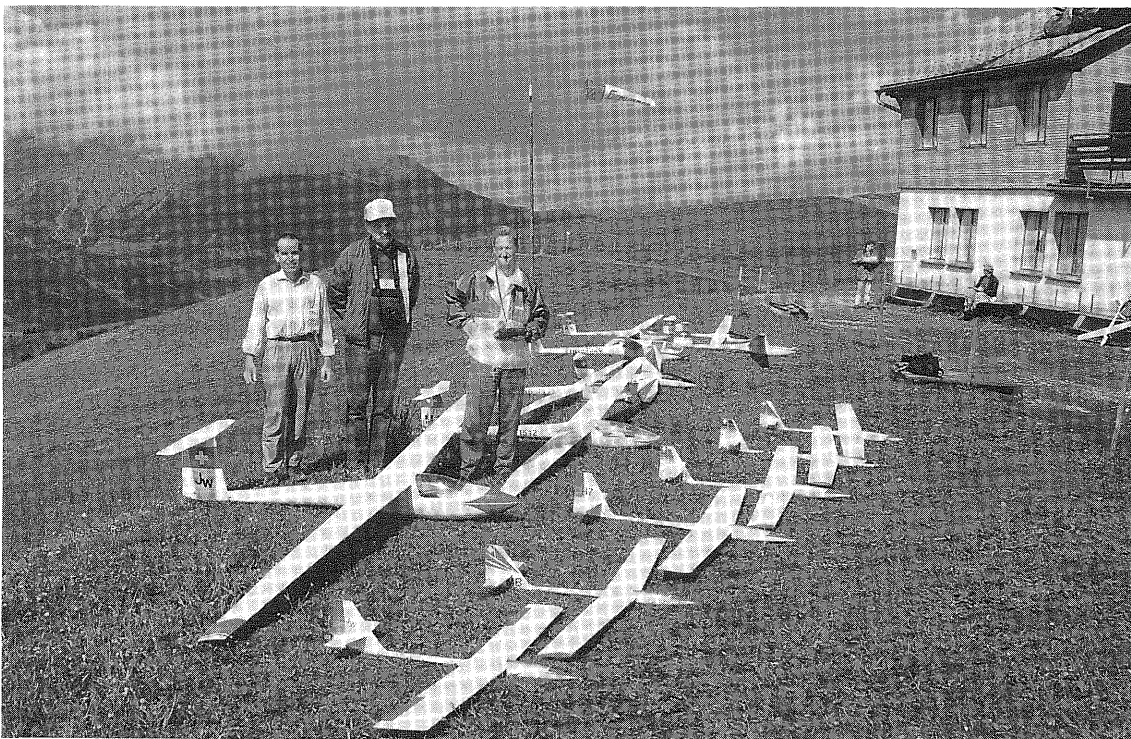
The mold for the fuselage, as explained before, was made by my friend Jürg. The mold for the rudder was made exactly like the stabs as explained above. While I can't explain the exact making of the fuselage mold (Jürg has done the job, and this process is more commonly known anyway). I only explain the actual making of the fuselage. The top coat is a white gel coat (polyester smells terribly!). A thin layer of glass (40 gm/sq m) was added before the 161 gm/ sq m (about 6.21 oz/sq ft, or 56 oz/ sq yd) Kevlar cloth and the graphite fiber strands were inserted. Kevlar is about 1/3 lighter than glass, but is very difficult to trim or cut off. The carbon fibers added in the skinny tail section of the fuselage are an absolute necessity for high speed flight. Each model tends to automatically dive downward as higher speeds are reached. The stabilizers must exert down force to maintain level flight and if the fuselage is not stiff enough it will bend, making control difficult. To make one fuselage takes me about eight hours.

Special parts for the Speedos were made by me in molded carbon fiber. These include the stab crank lever (with two ball bearings) and the fuselage wing rod carrier (with three roller bearings). The wing joiner rod is 8 mm steel. The roller bearings ensure easy rotation of the wings. First Speedo '87 models had their wings twisted by directly driving the leading edge pins by short links from a Multiplex servo. Currently we have switched to small molded carbon fiber crank levers having slots to drive the L.E. pins. The levers have molded-in steel wear protection surfaces in the slots. I have used a Multiplex Royal radio for years and am very satisfied with it.

I was not really worried before the maiden flight of my Speedo '87, but after investing about 800 hours of work (I worked on this project for three months straight without a regular job), one kind of wonders what is going to happen. It flew beautifully without any major adjustments! After the first few turns, I noticed its very stable and uncritical flight behavior. I could barely stall it, and when it did, it went into a smooth downward curve. Its restitution (ability to convert speed into height) surprised me because it was so much better than the Speedo '84, which was very good itself. Because of its low speed flying

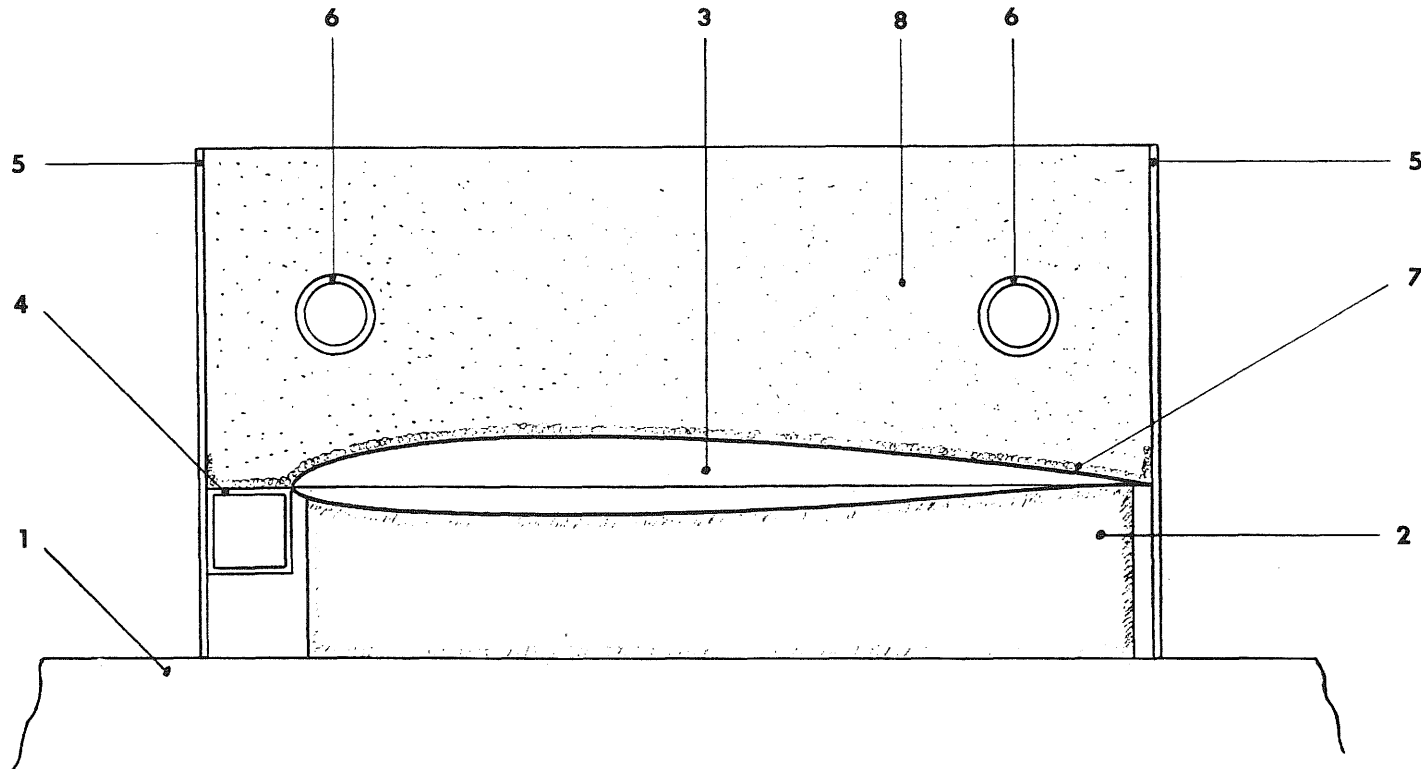
capabilities, I can take advantage of even the smallest thermals or updrafts. With its thin 9% airfoil, it is also a very fast glider and speeds up to 150 MPH are easily reached. Due to its high penetration, the Speedo '87 is also perfect for aerobatics. After about the first two hours of intensive flying, I could see it easily outperformed its smaller brother. Time after time the Speedo '87 has been admired by amazed glider pilots and I can say, without bragging, that it pretty much outperforms every glider I have ever flown or owned within my 17 years of flying gliders. I hope you can see that with that kind of involvement you can't mass produce, or put a realistic price tag on this model. For these reasons, Jürg and I have agreed not to sell this model.

Martin Bamert



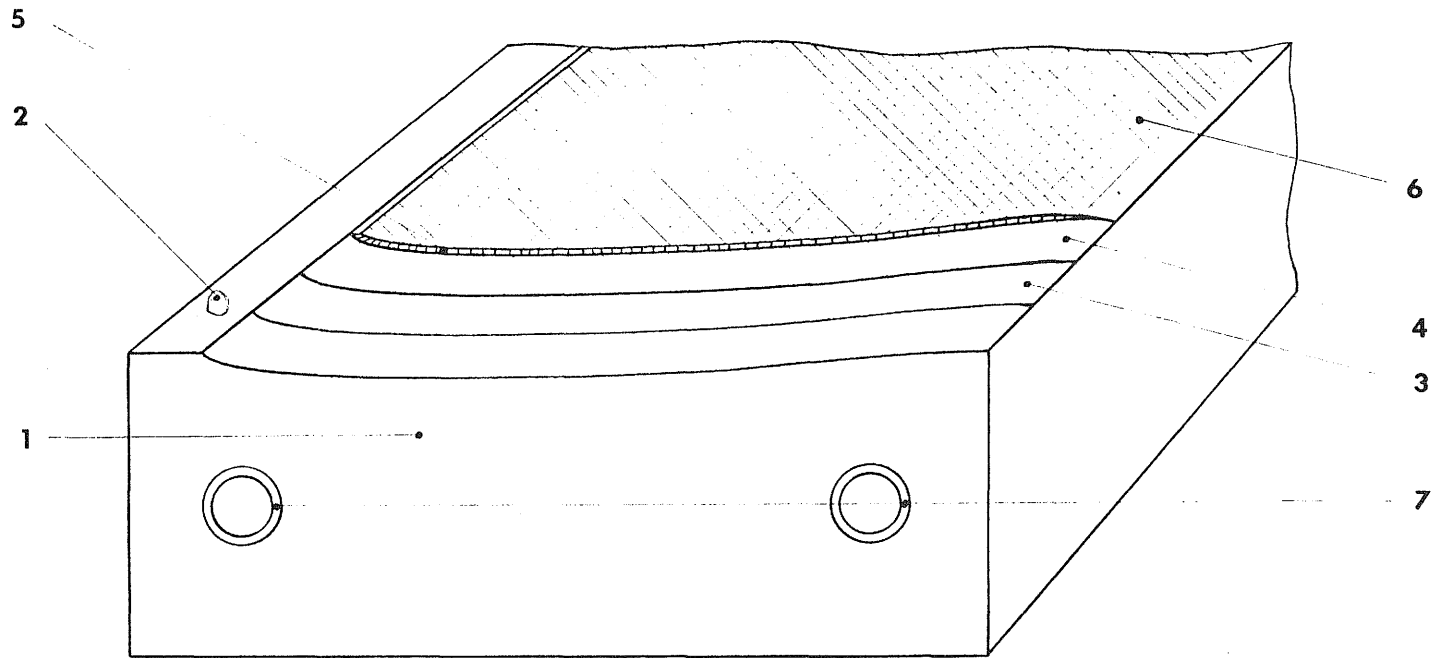
Byron Blakeslee with Jürg Wermuth and Martin Bamert displaying the "Speedo" models as well as both of their Grosseglers (giant gliders). Jürg owns the 5M "Club Libelle" in the foreground, and Martin's scratch built 5M "DG-202" is to the rear.

Drawing #1



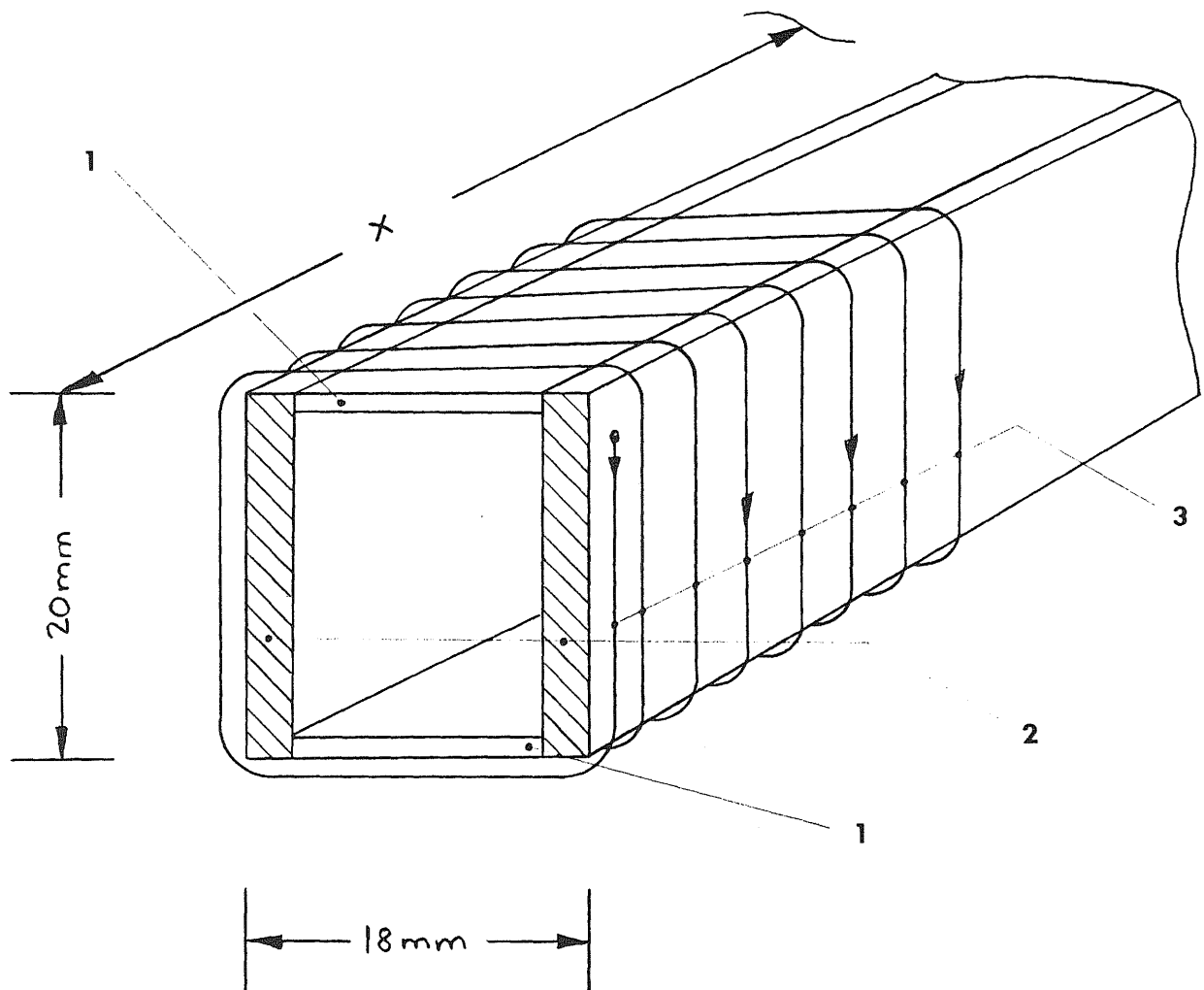
1. Straight table (not warped)
2. Lower foamcore (left over from original wing)
3. Finished masterwing
4. Anodized aluminum profile (will yield flat area in front of leading edge)
5. Sideplates (about 1/16" aluminum)
6. Steeltubes (help to separate molds)
7. Grey Molding resin
8. Quartsand mixed with resin
(mixing ratio: 10 parts sand and 1 part resin)

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Drawing #2

1. Mold
2. Positioning bolt
3. White gelatine coat
4. 40 gm/sq meter glass cloth
5. 1.5mm Balsawood
6. 120 gm/sq meter glass cloth
7. Steeltubes (dia. about 3/4 up to 1")



Drawing #3

1. Prefabricated carbon 1mm thick (1mm plywood can be substituted)
2. Sideplates 3/32" plywood
3. Carbonstrands (40k) soaked with resin and tightly wrapped around mainspar
- X Length of spar about 10% of final wingspan

2/6/89 MB



A postcard named "Eldorado of Model Glider Pilots" from the beautiful Hahnenmoospass region in Switzerland. Postcard courtesy of Photo Klopfenstein Adelboden.



Figure 1: Blue foam cores with the prefabricated fiberglass skins. Skins will be epoxied to foam cores. They consist of a 295 grams per square meter (about 1 ounce per square foot) glass cloth soaked with epoxy resin.

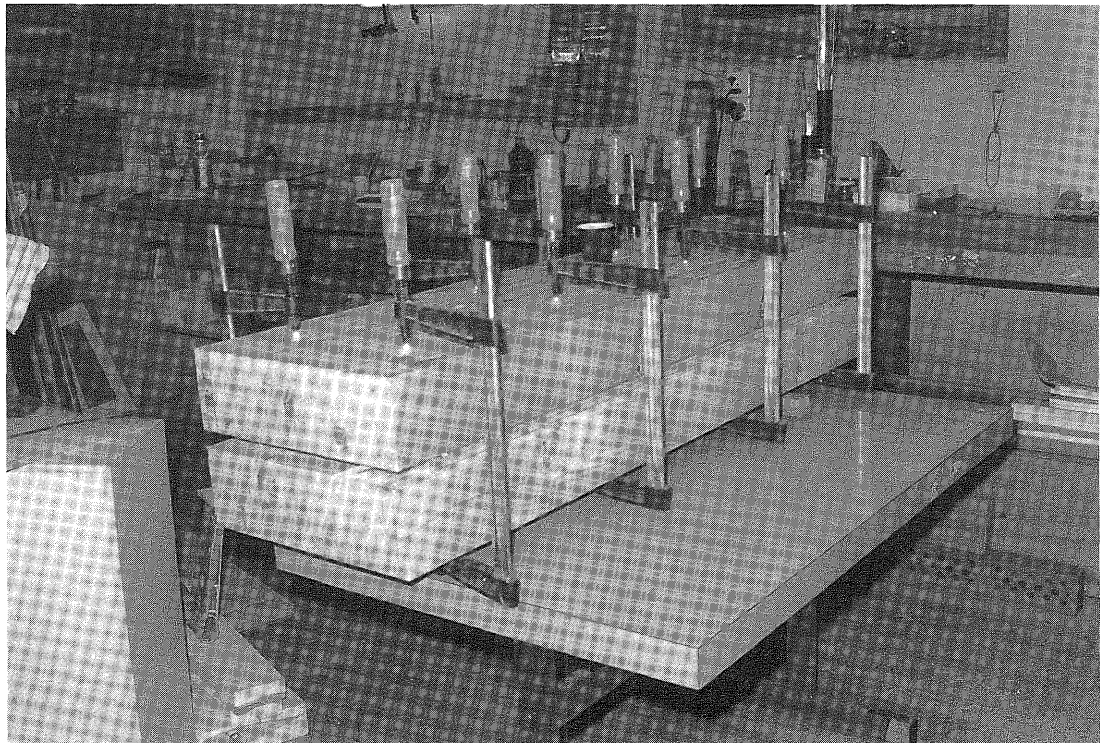


Figure 2: Butcher blocks between which the fiberglass skins are epoxied to the foam cores. The eight clamps apply even pressure for both wings.

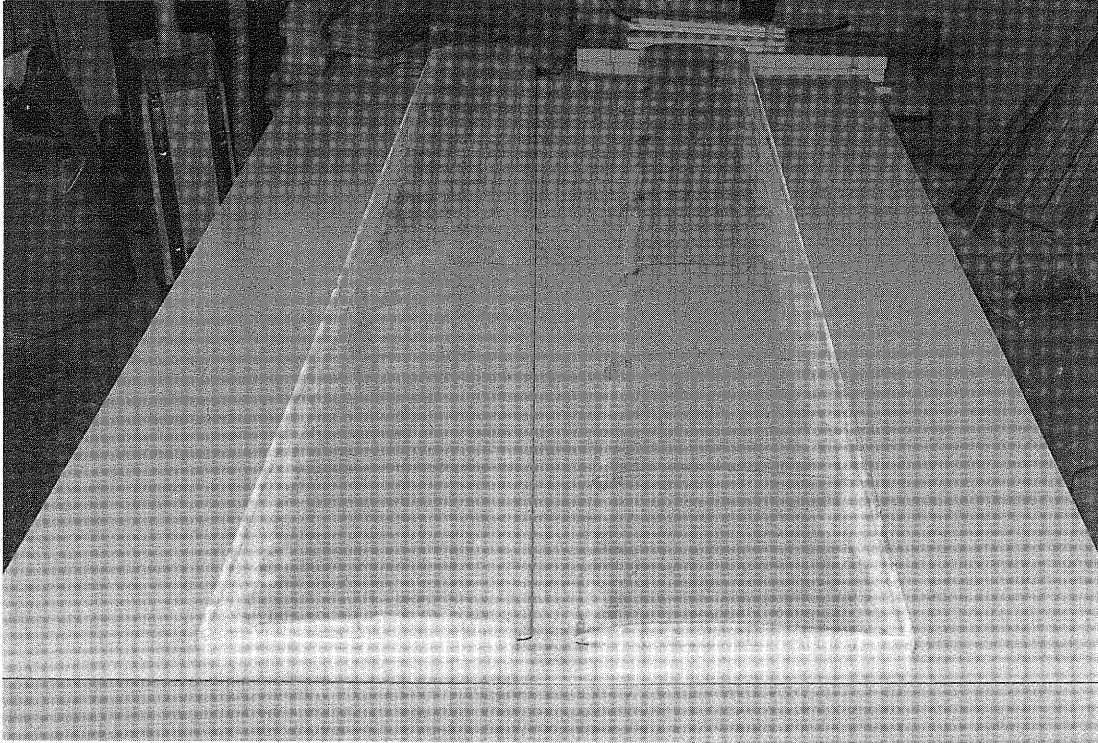


Figure 3: Wings with added obechi leading edges. Notice the eight equi-spaced stations at which the airfoil is checked for accuracy.

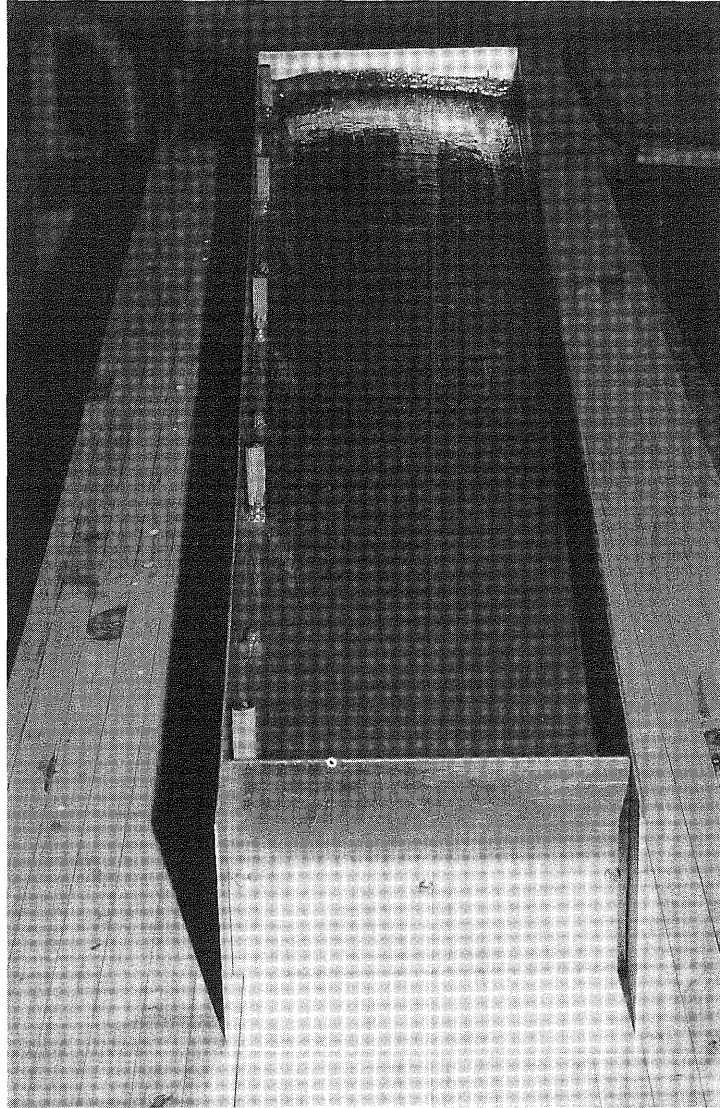


Figure 4: Wing supported on foam core (not visible), surrounded by aluminum frame and with the molding resin applied. Easily visible are positioning bolts on the left side of the mold.

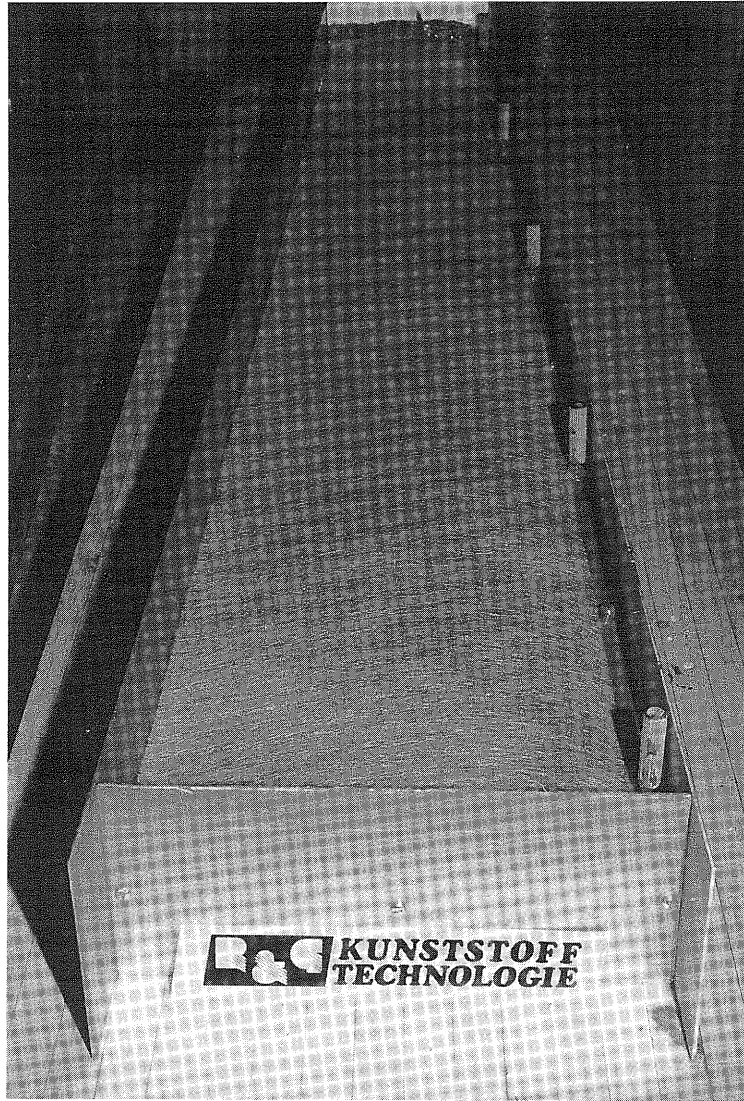


Figure 5: Bi-directional glass cloth on top of molding resin.

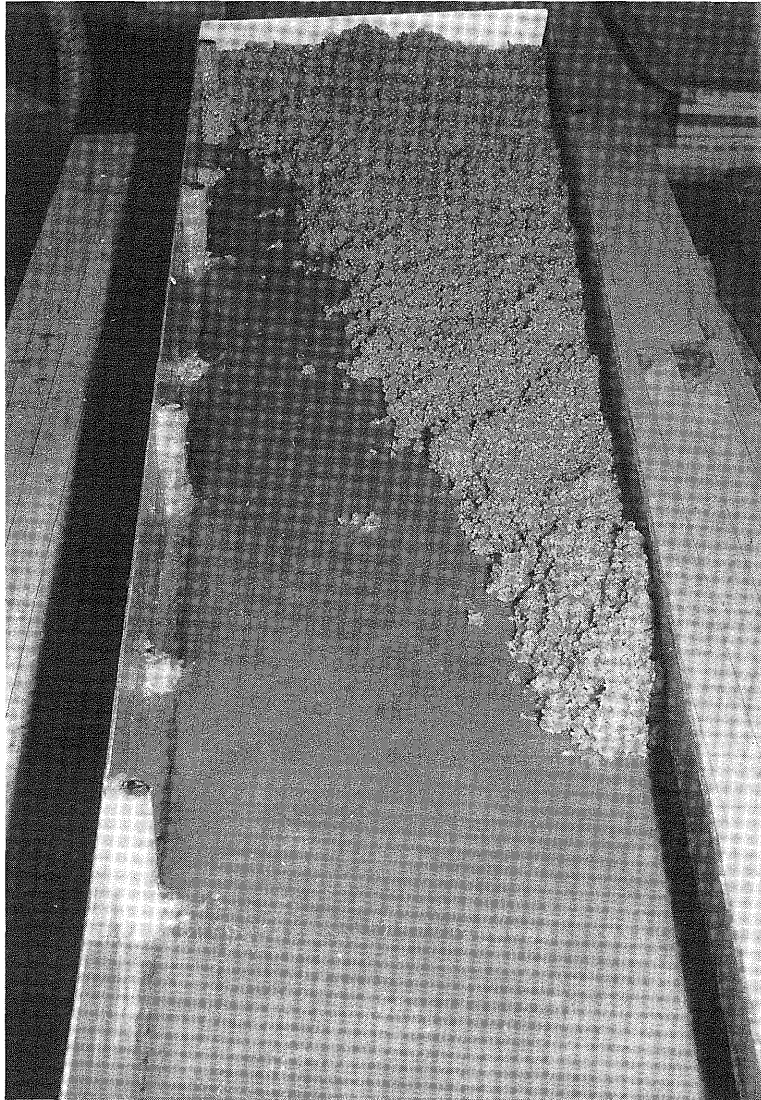


Figure 6: Adding the quartz sand and resin mixture to the mold. This mixture has to be well compacted to prevent air holes in the mold.

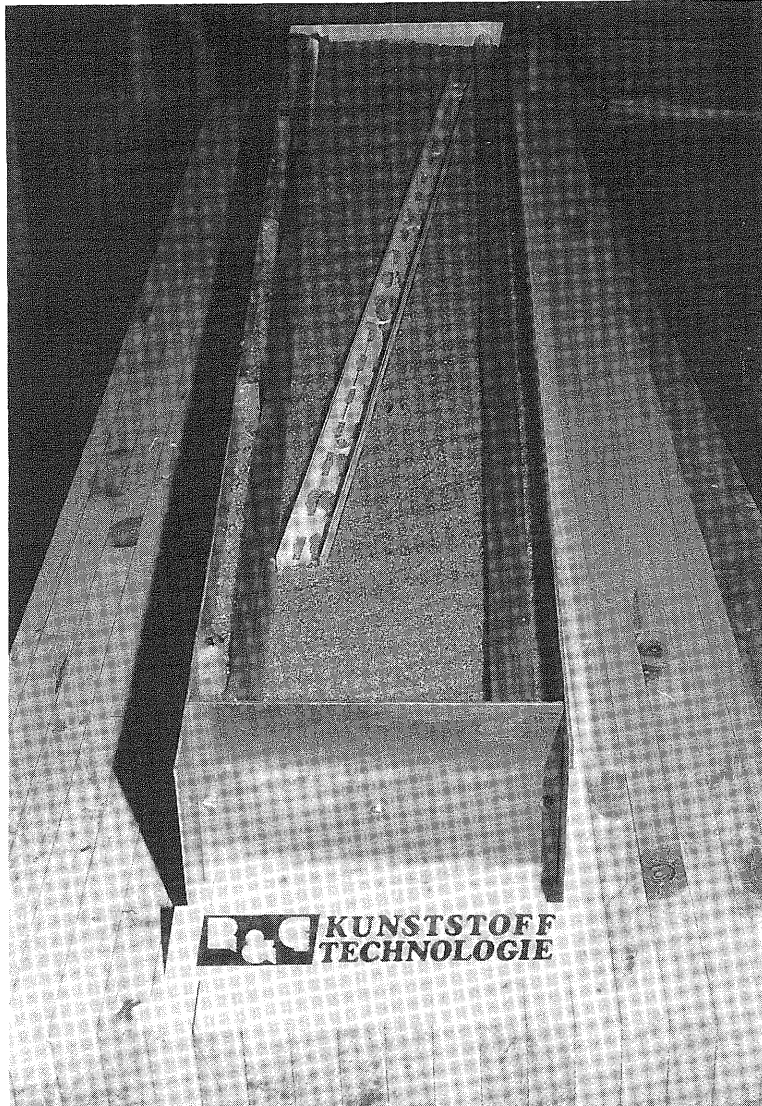


Figure 7: Steel tubes as well as another U-shaped diagonal reinforcement in place. The mold is now filled with additional quartz sand-resin mixture up to the top rim of the aluminum frame. Again, the mixture must be well compacted.

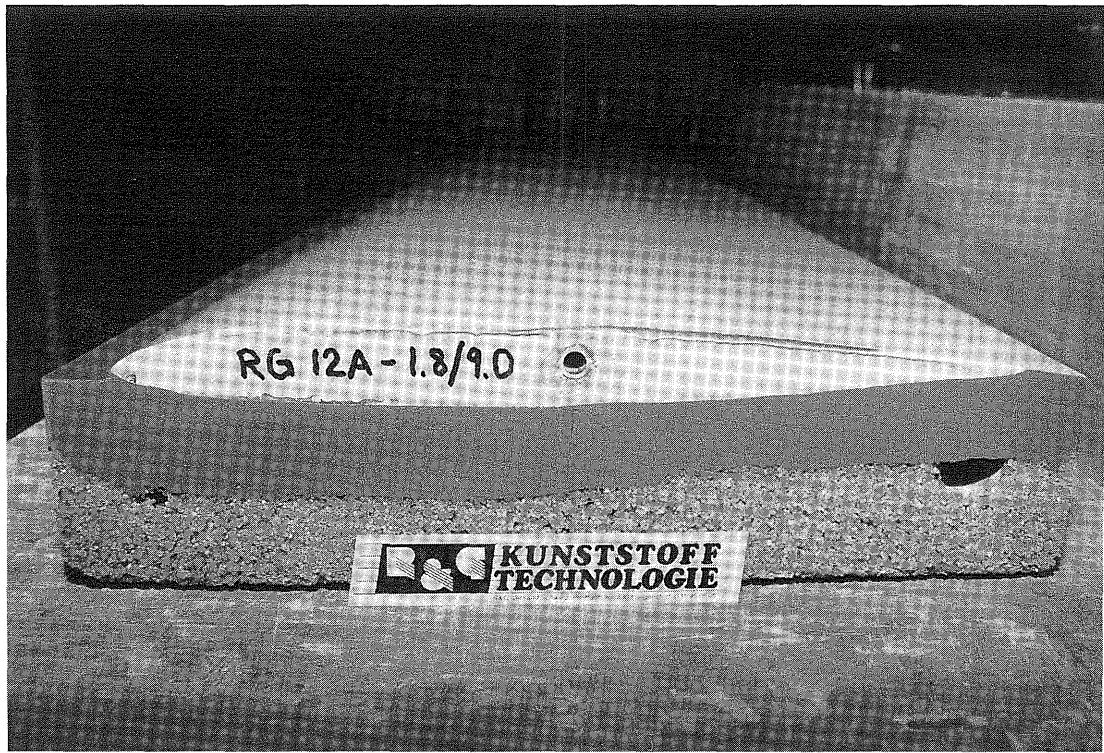


Figure 8: Completed lower right wing mold. The aluminum frame has been removed to show the set-up. Recognizable are the two steel tubes. At this stage the master wing pattern is not removed in order to maintain perfect alignment of the upper and lower mold.



Figure 9: Close up of the lower half of the mold. Clearly visible is the positioning bolt and nut to pull the halves together in the molding process. The airfoil used is RG 12A-1.8/9.0.

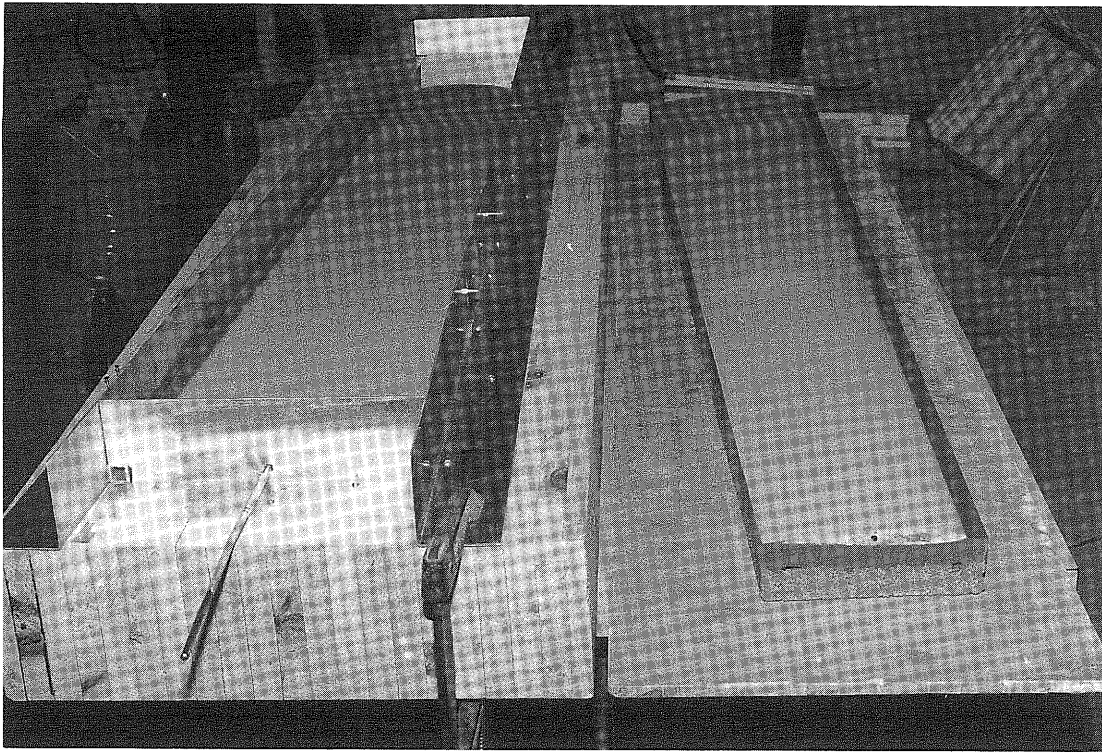


Figure 10: Left side - The left wing upper mold-half ready to be molded. Right side - The finished lower mold - half for the right wing.



Figure 11: Left side - Left upper wing mold to be completed. Right side - Completely finished molding process of right wing.

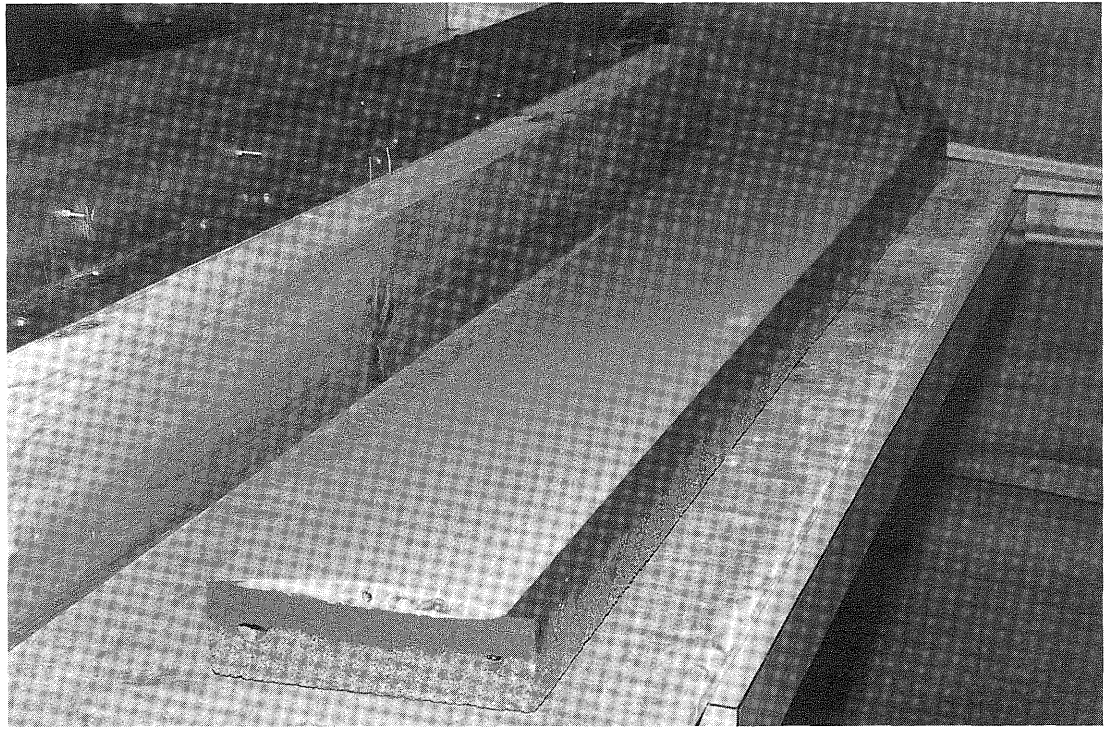


Figure 12: Close-up of finished right lower wing mold.

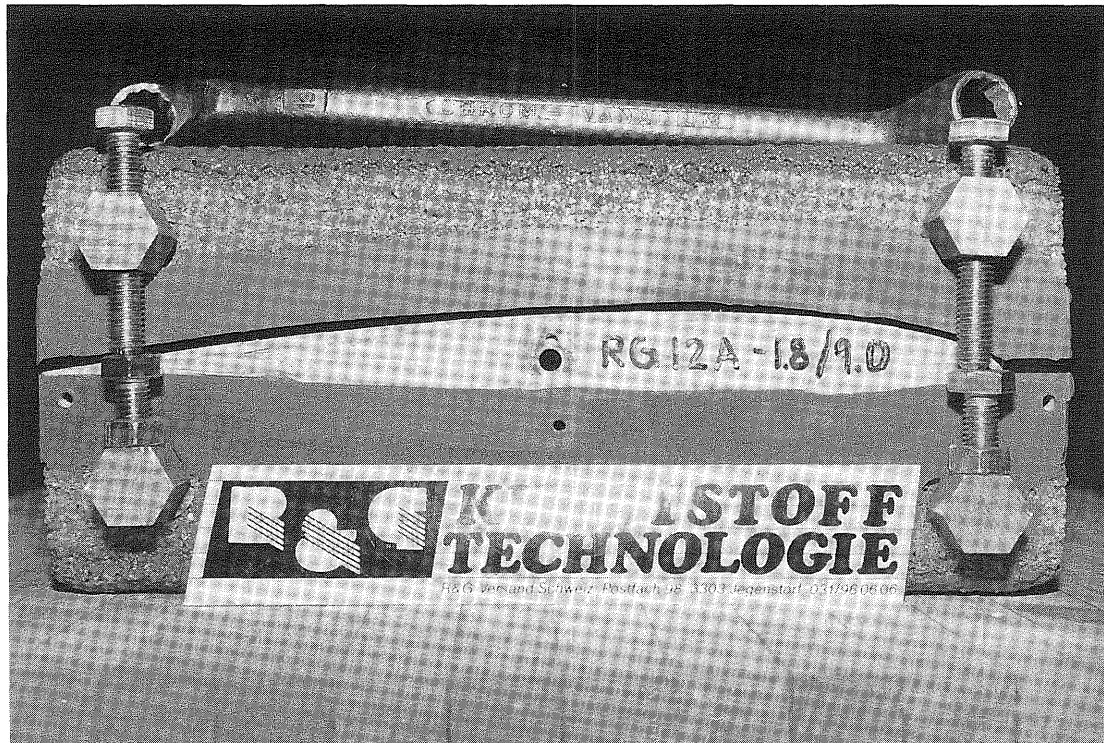


Figure 13: Finished left wing mold showing the separating mechanism. The steel tubes previously placed in the molds are being used to apply separating forces originating from the top left and right screws. As both screws are turned, they apply pressure to both bottom steel tubes.

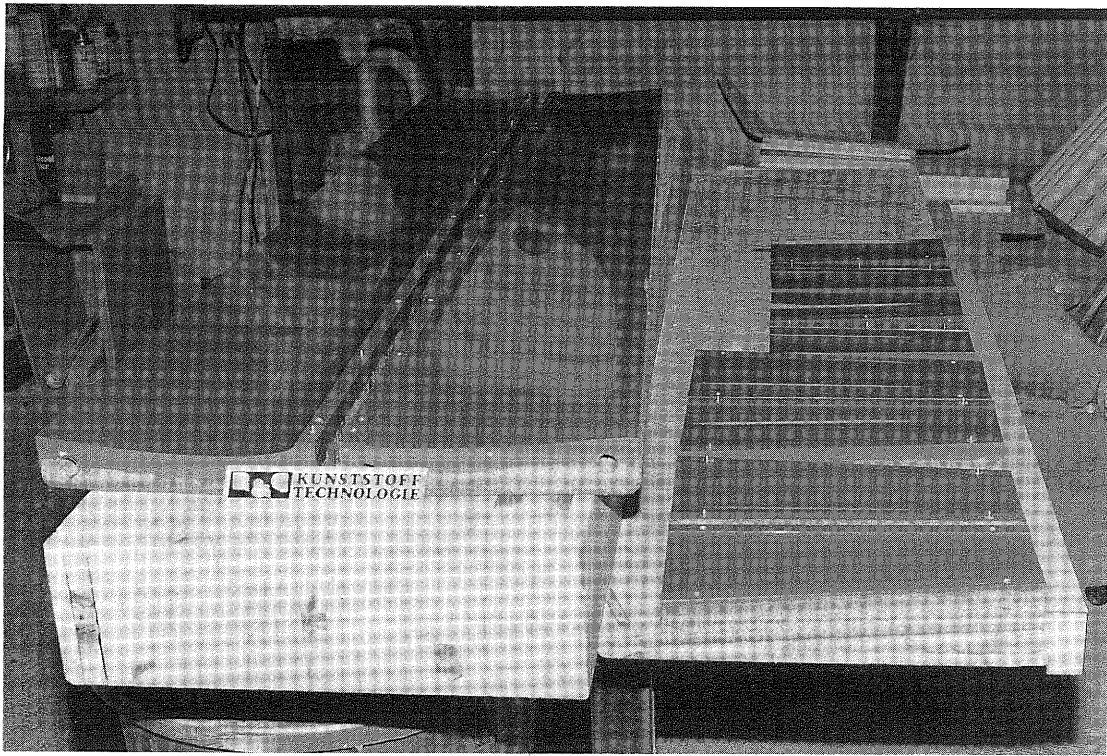


Figure 14: Completed wing and horizontal tail molds. Easily visible are the positioning bolts.

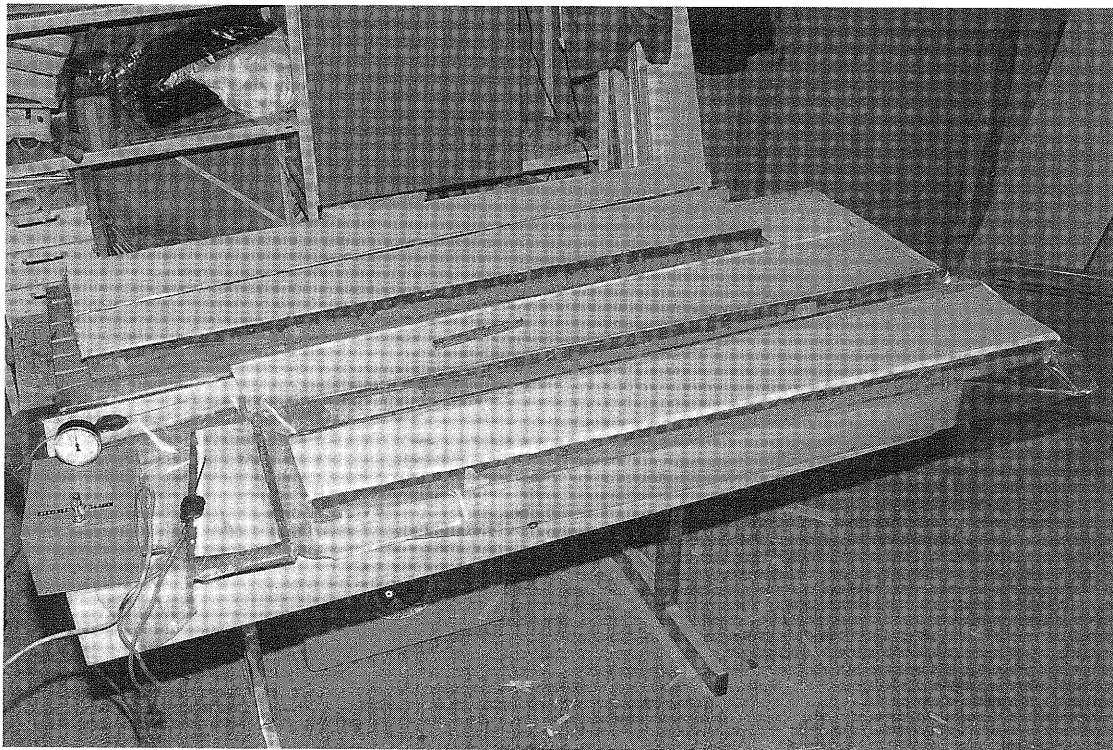


Figure 15: Vacuum bagged wing molds. High vacuum can be used because no foam is inside the bag. The vacuum pump is located on the left side.

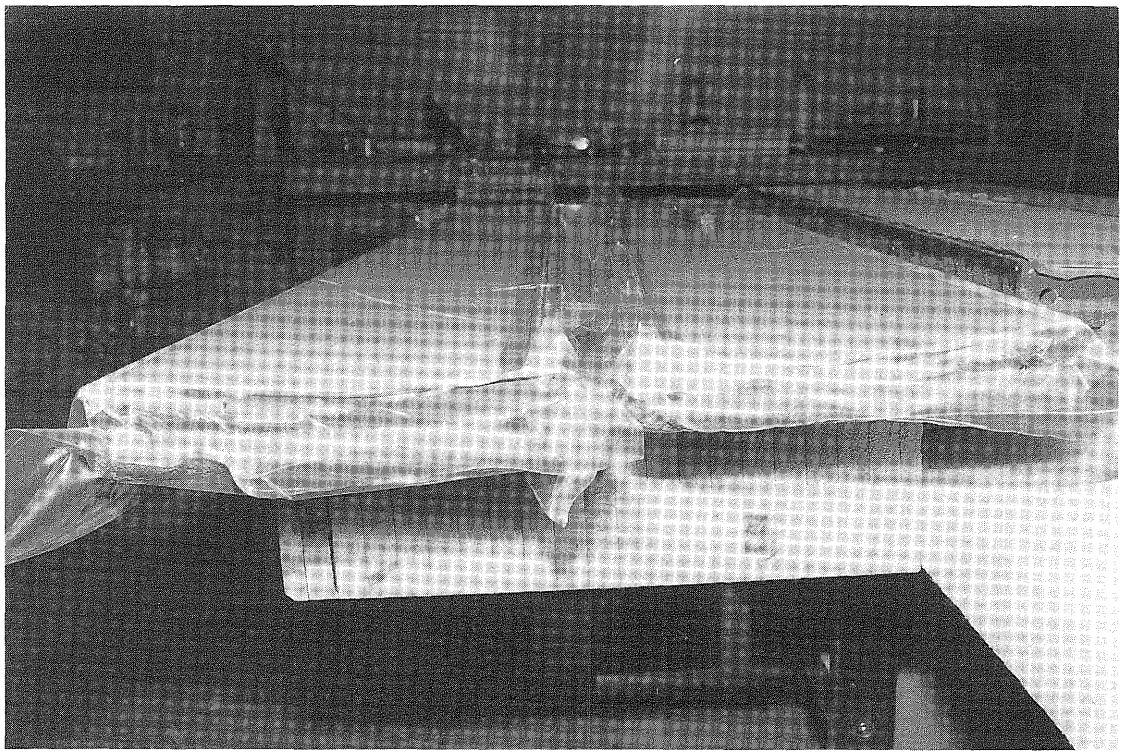


Figure 16: Close-up of the vacuum bagged upper and lower wingmold.



Figure 17: The main spar and auxiliary spars (consisting of roofmate foam which in the USA is more commonly known as Styrofoam or blue board) are being glued to the lower moldings of both wings with epoxy resin. Lead weights are used to press the spars down tightly to the skin moldings.

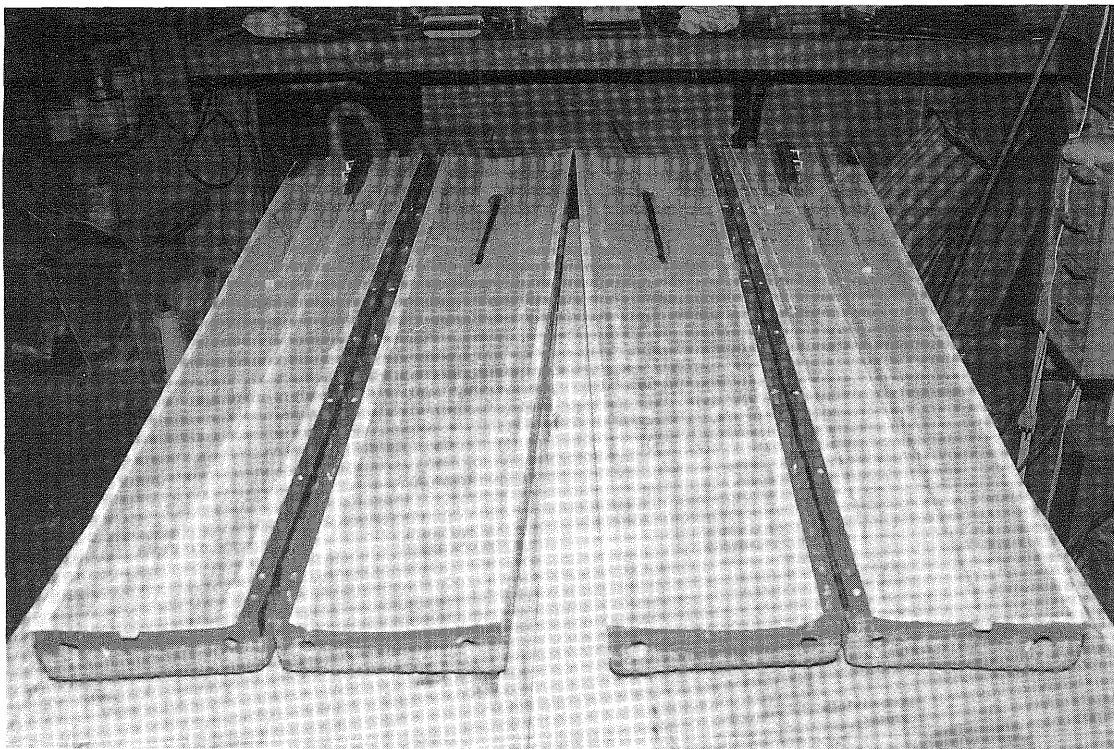


Figure 18: All of the spars are in place, and the wing skin moldings are ready to be epoxied together. Prior to joining the moldings, both the spars and the moldings have to be checked for a snug fit.

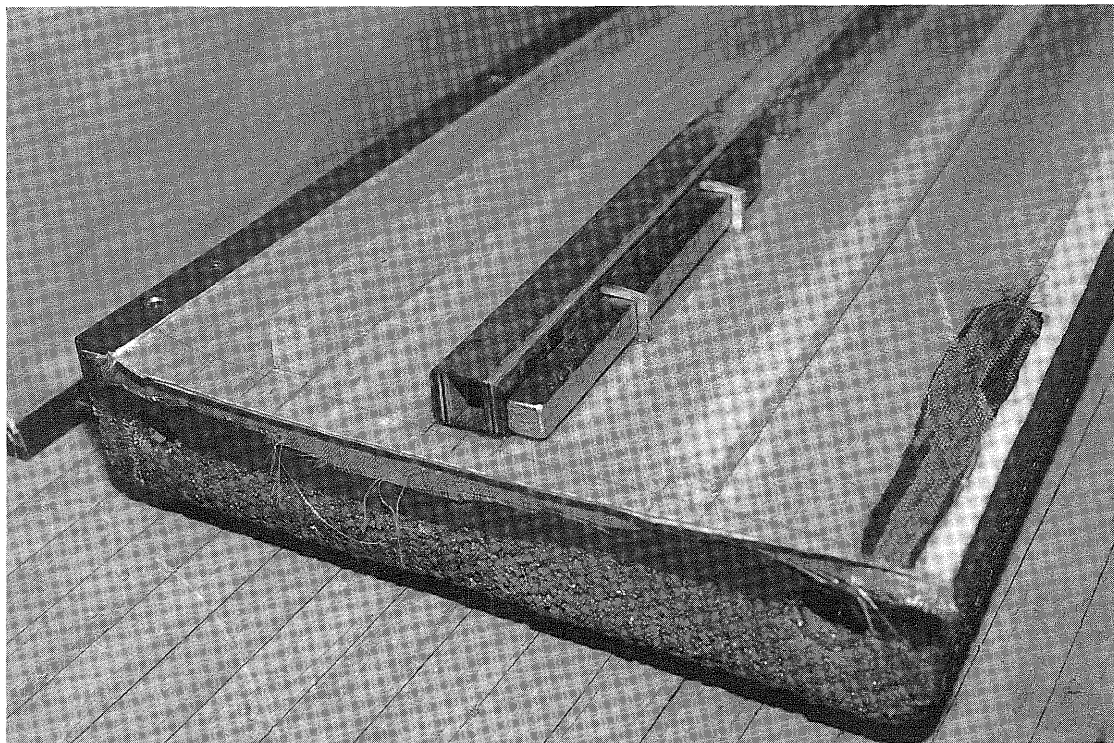


Figure 19: The right lower mold, main spar and ballast compartment. The auxiliary spars are visible on the left and right side of the main spar. They establish the spacing between the upper and lower skin moldings of the finished wing.

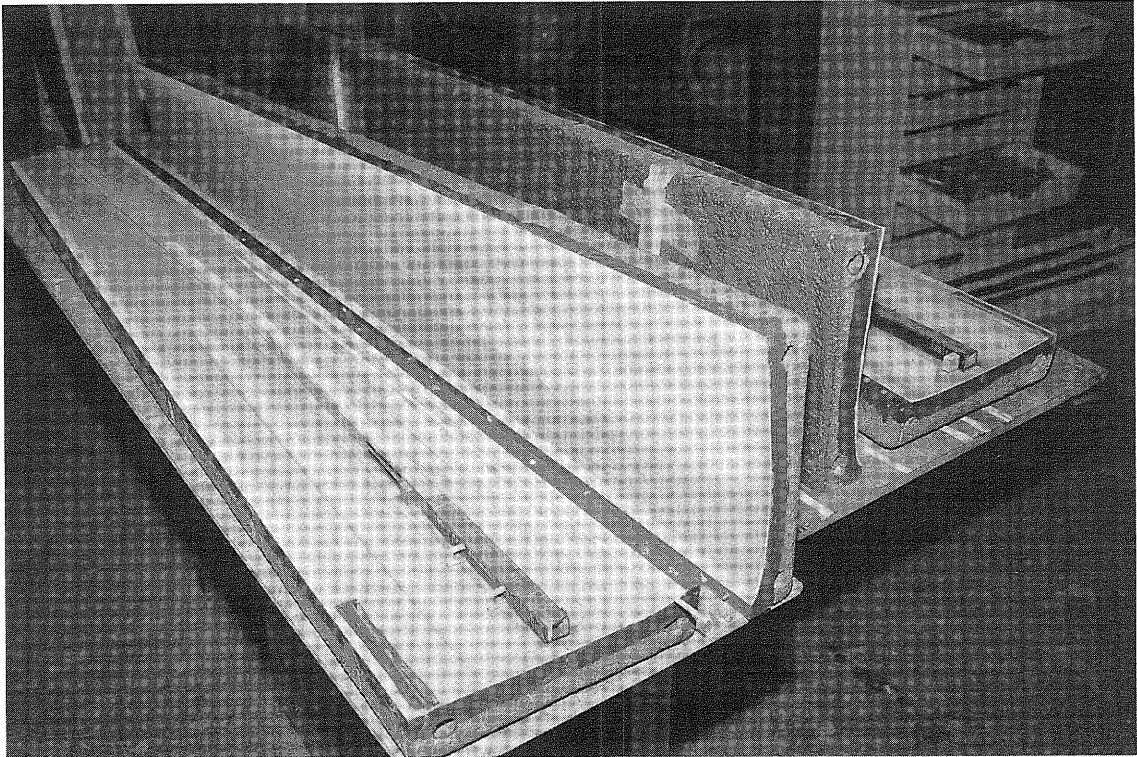


Figure 20: Moldings ready to be epoxied together.

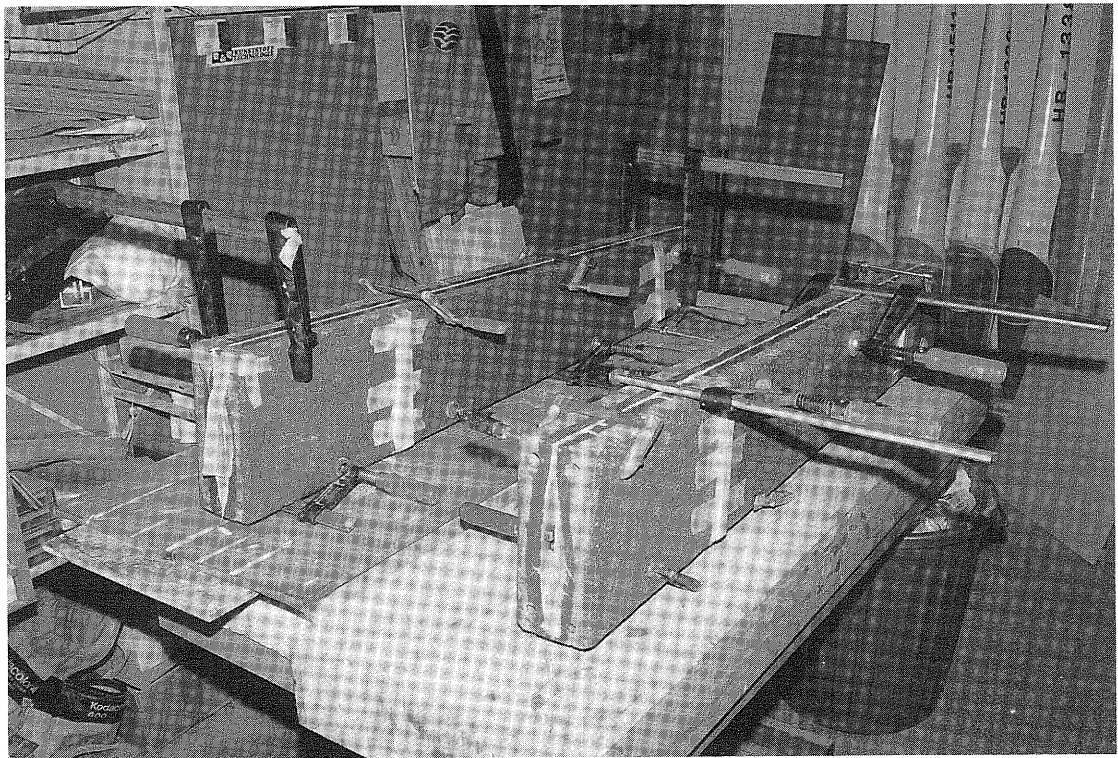


Figure 21: The final joining of the wing moldings. Screws or C-clamps are used to hold the molds tightly until the epoxy resin is cured. The molds are placed with the leading edges down. Epoxy resin applied to both leading edges prior to joining the upper and lower moldings, flows down into the seam and increases the bonding surface.

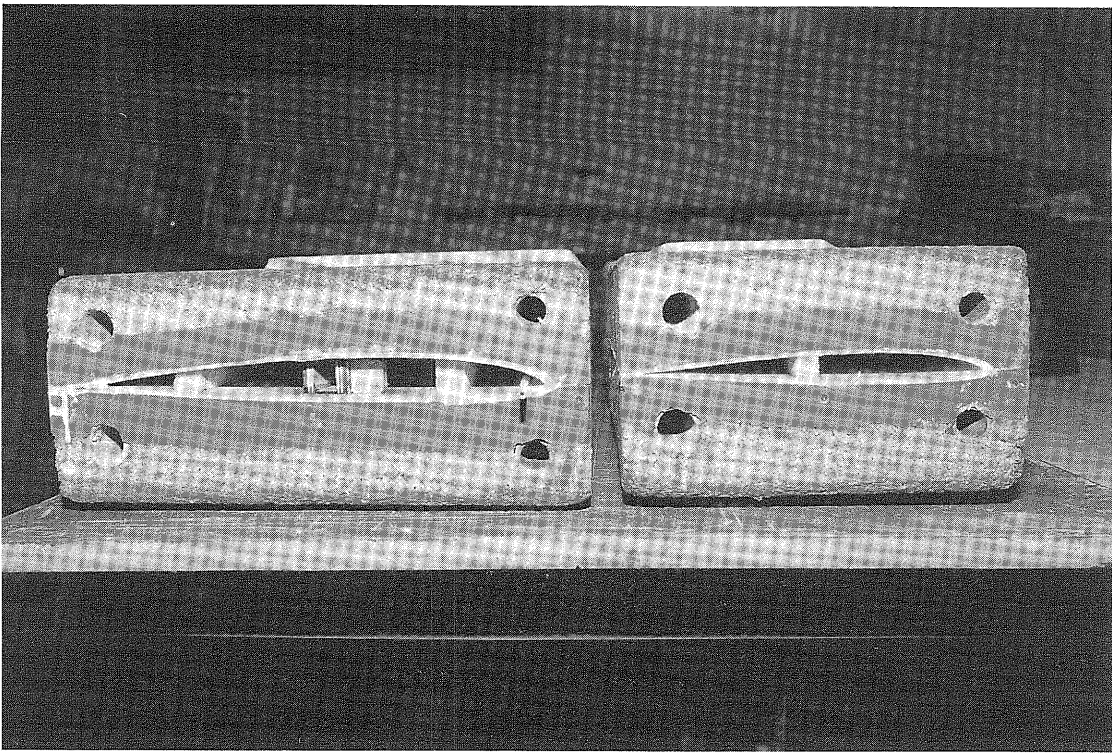


Figure 22: View of the root and tip section of the finished wing which is still in the mold. Wing molds can be separated as shown earlier, once the epoxy is completely cured.

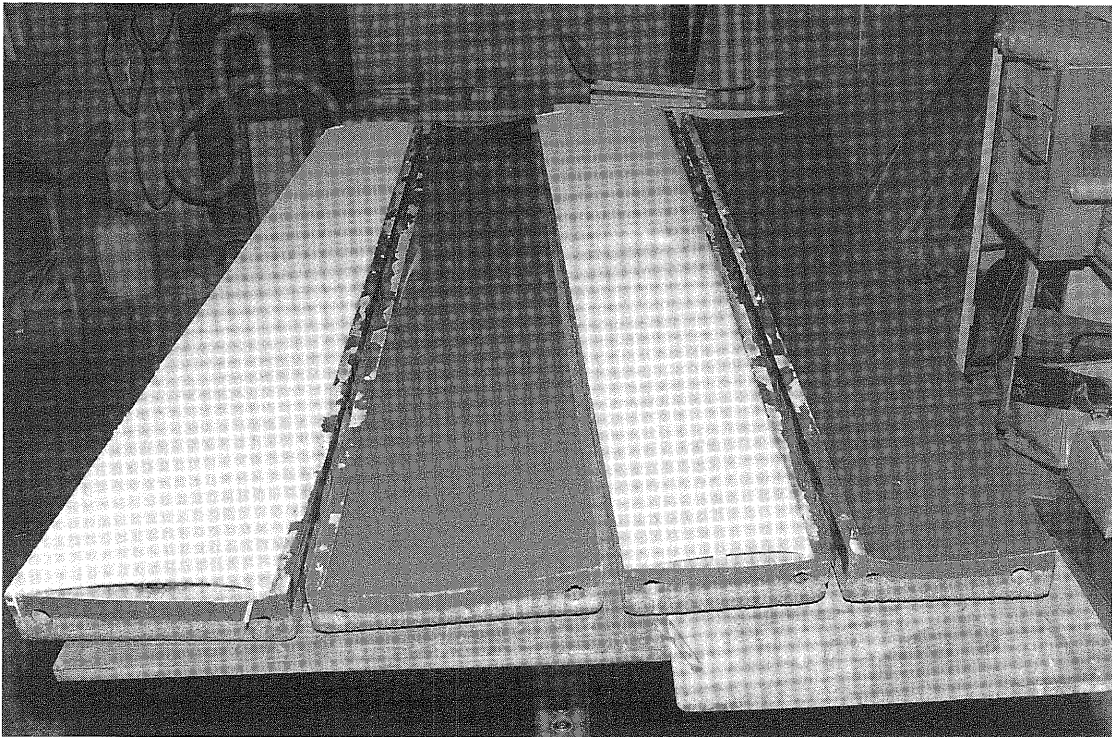


Figure 23: Both upper wing molds have been removed exposing the right and left wings still "attached" to the lower molds. It is imperative to use dependable and proven release agents in order to insure an easy "birth" of the wing. Hard to separate wings can easily be destroyed; and more seriously, damage your wingmolds!

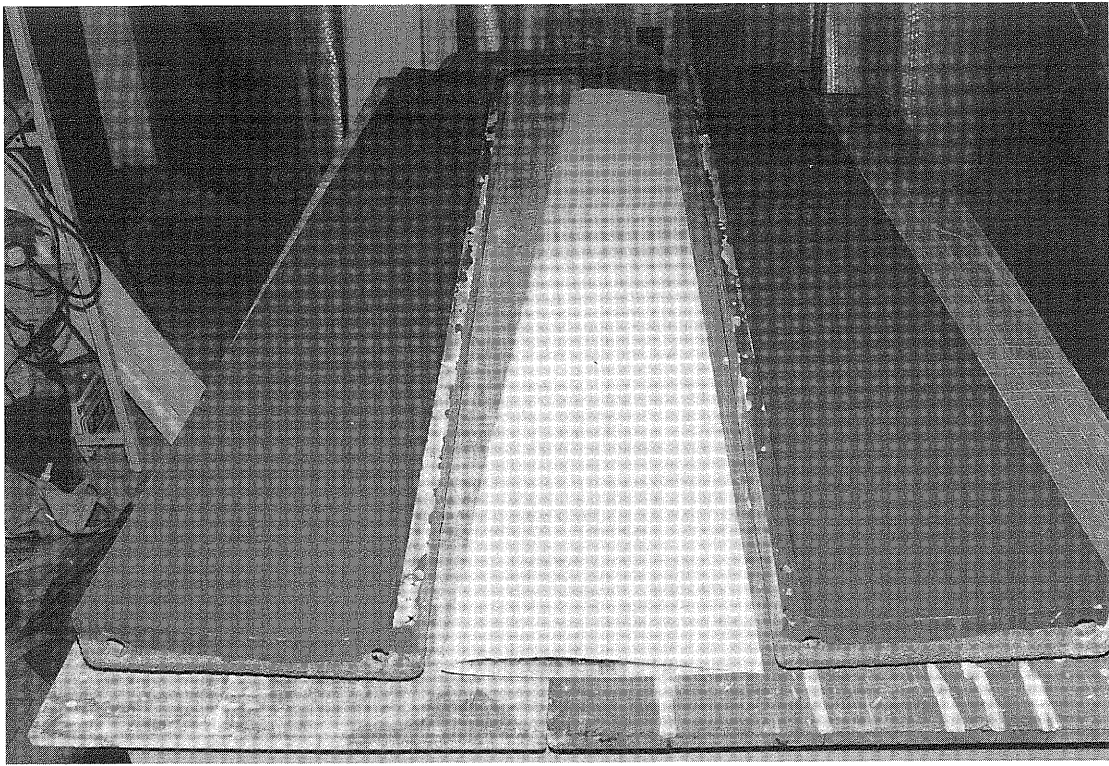


Figure 25: Upper and lower wing molds with the final product; a glass-molded wing section.

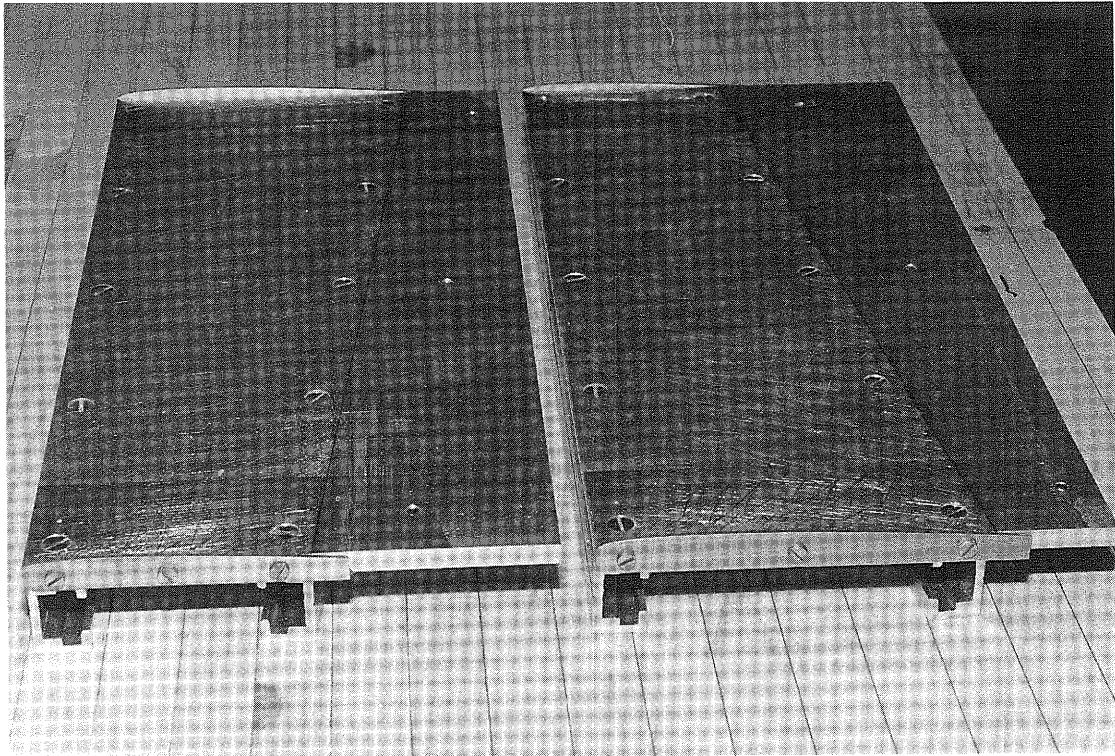


Figure 25: Aluminum baseplates on which the horizontal tail upper and lower master molds are being built. Notice on the ends of each baseplate exactly half of the NACA 0006 airfoil template is protruding. It is very important that the templates be attached accurately in order for the upper and lower molds to align.

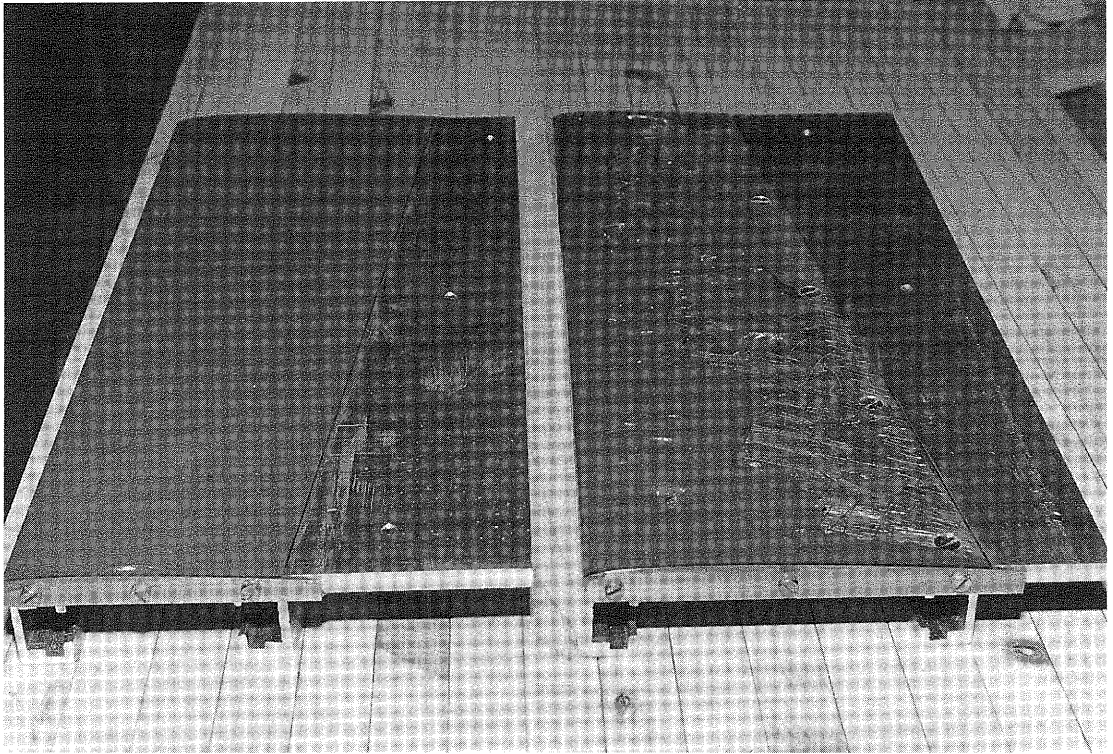


Figure 26: The horizontal tail upper and lower mold halves in the process of being built.

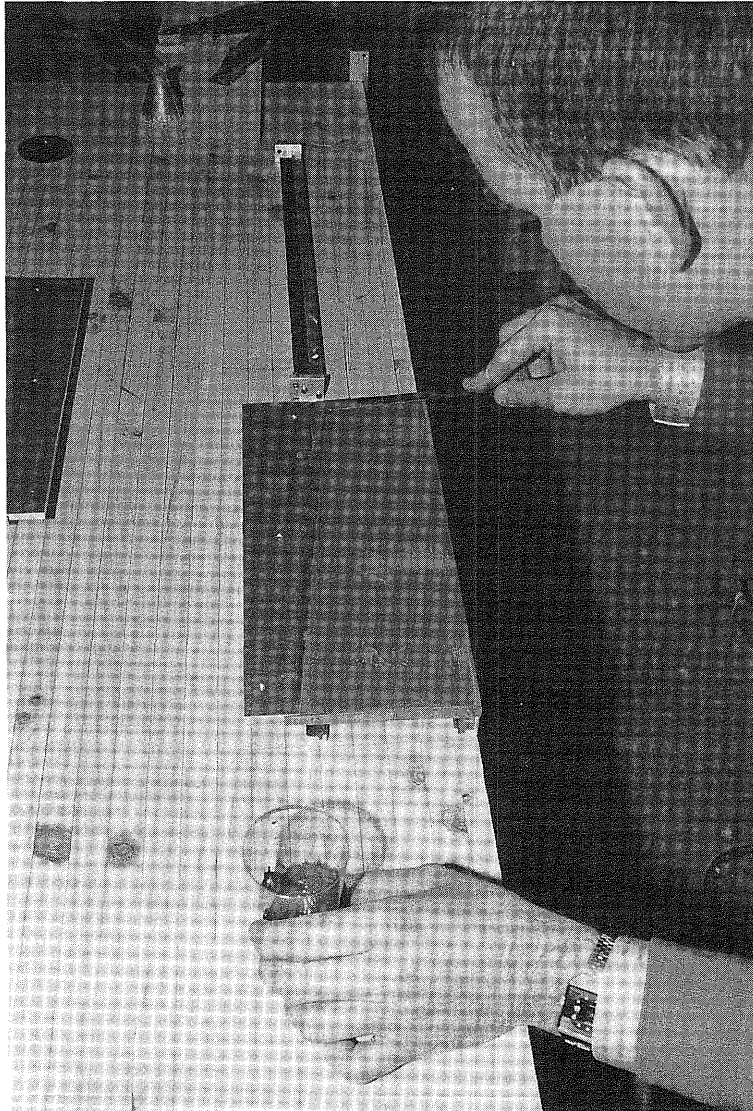


Figure 27: Spreading of the molding resin to the horizontal tail mold half. Easily recognizable is the hinging point of the extended straight rule, located at the left of my forehead.

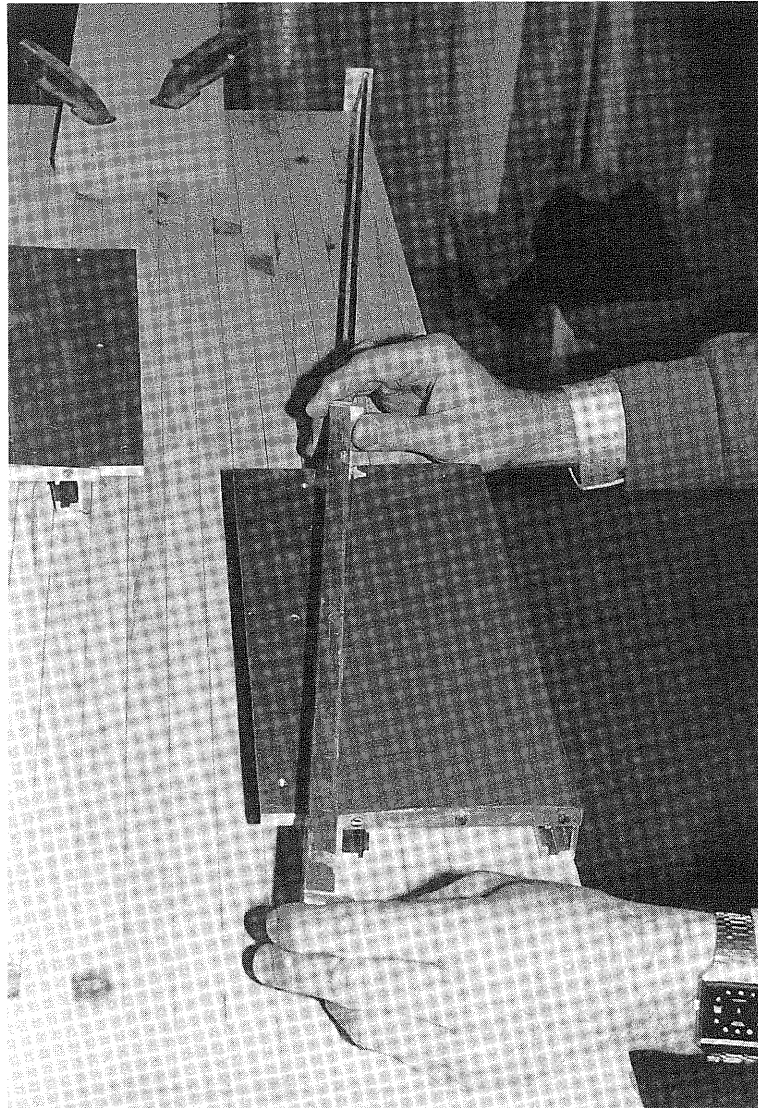


Figure 28: The "Scraping" procedure starts at the trailing edge and proceeds to the leading edge. To achieve a proportionate and even traveling distance over the root and tip templates, the scraping rule is extended and hinged at the converging points of the extended lines of the leading and trailing edges.

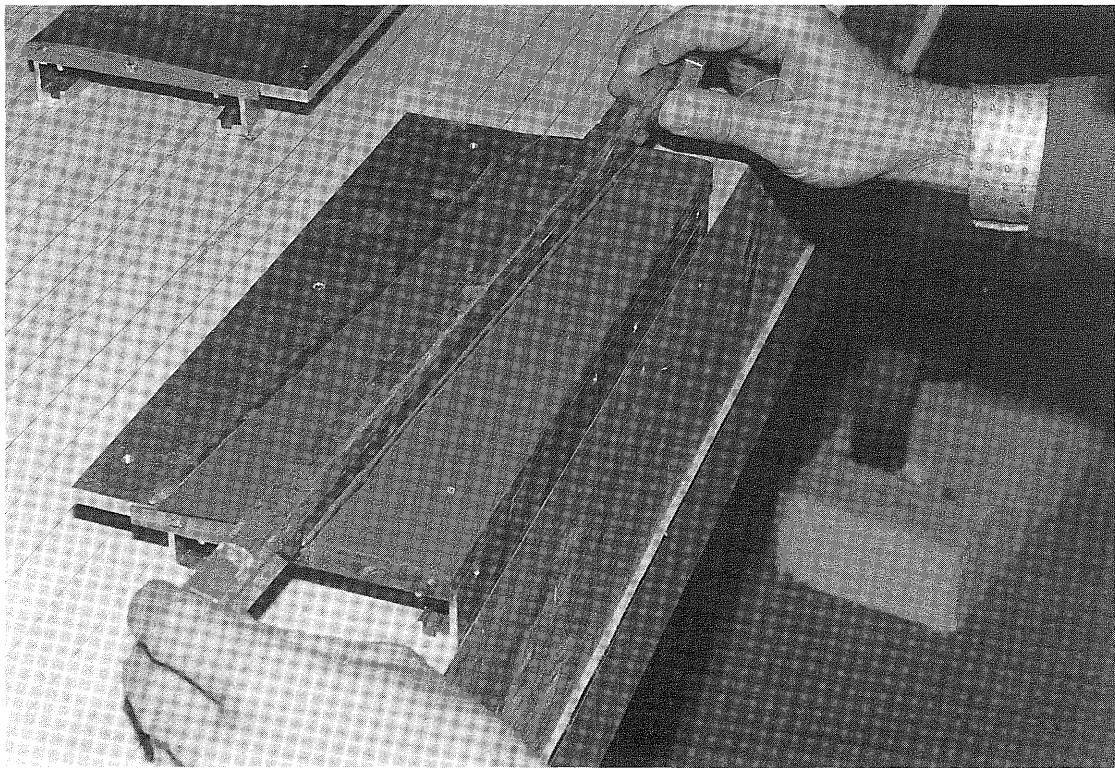


Figure 29: Close-up of the "scraping" process half way through.

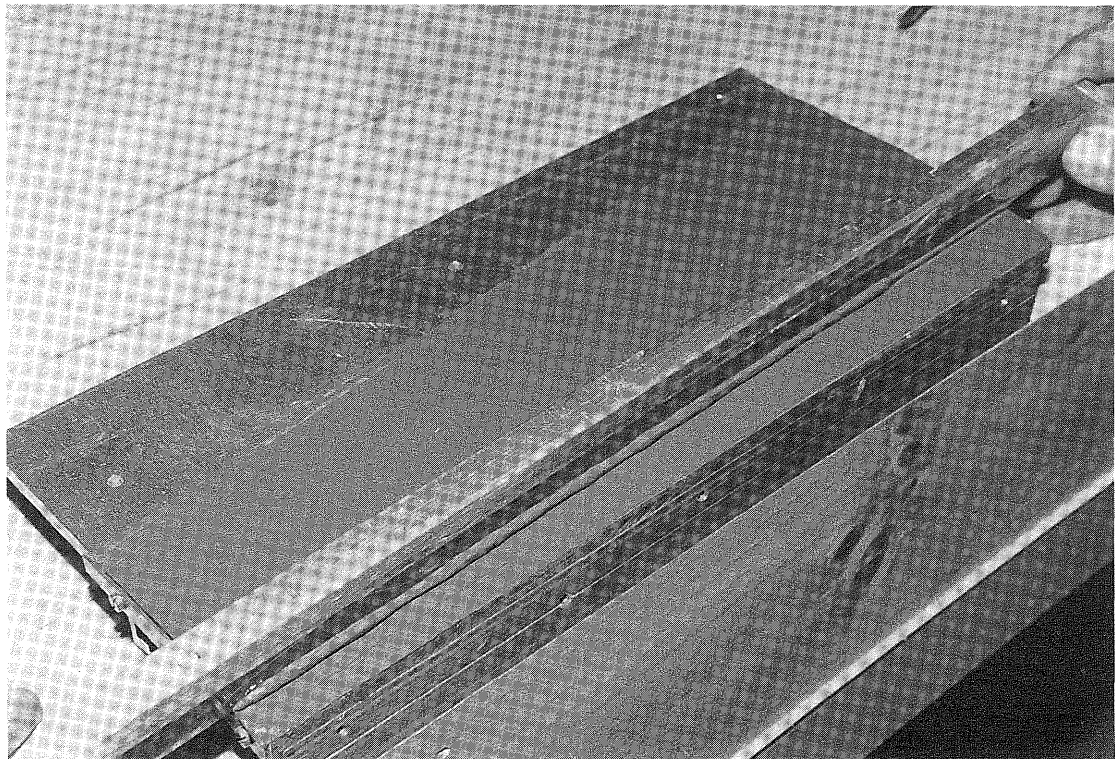


Figure 30: The "scraping" process approaching the leading edge.

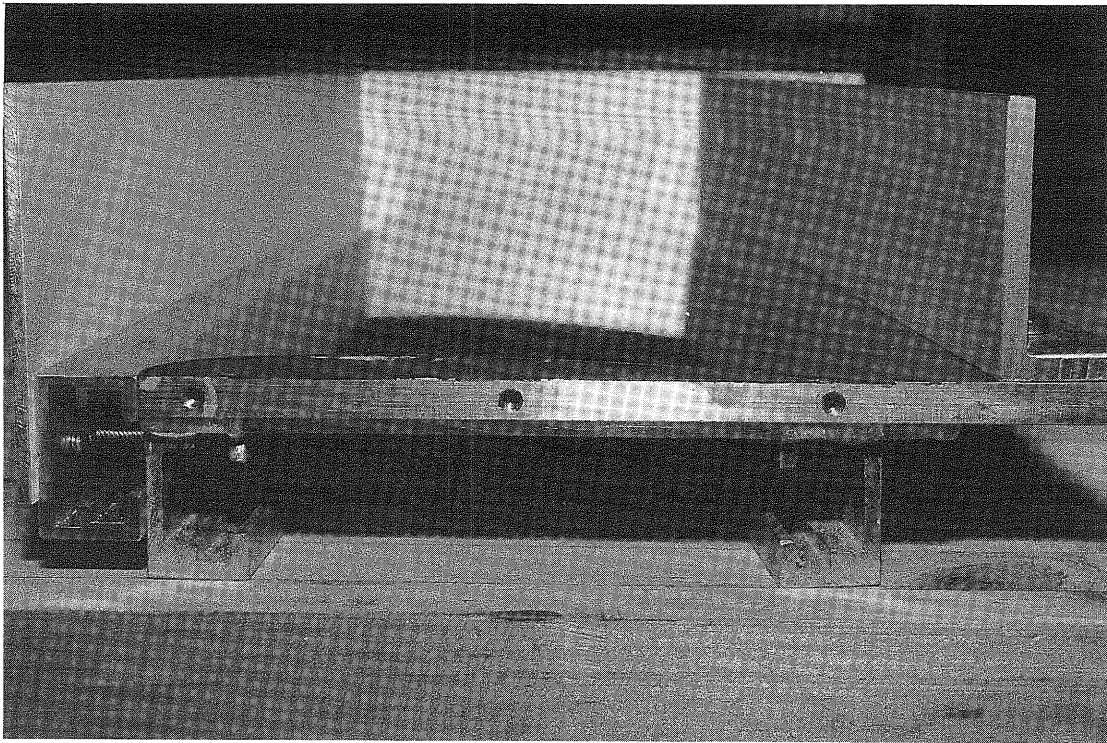


Figure 31: The root template is removed to expose the built-up master mold of half the horizontal tail. Seventy five percent of the molding frame is already installed. Notice the reflection on the perfectly straight and polished surface.

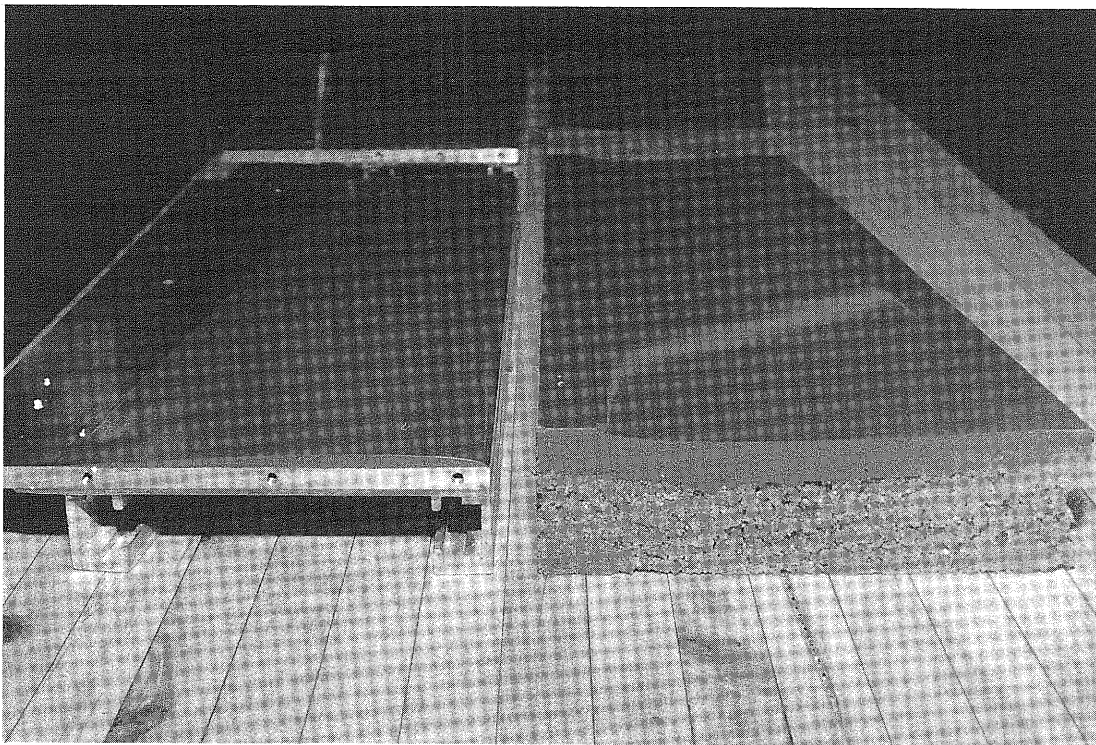


Figure 32: On the left side is the positive master form of the horizontal tail. On the right side is the finished mold of one half of the horizontal tail.



Figure 33: The finished horizontal tail molds of the smaller "Speedo 84" model on the left, and the "Speedo 87" model on the right.



Figure 34: The horizontal tail mold is placed in a vacuum bag to press and glue the 1/32" thick balsa wood into the mold. The vacuum pump is on the left.

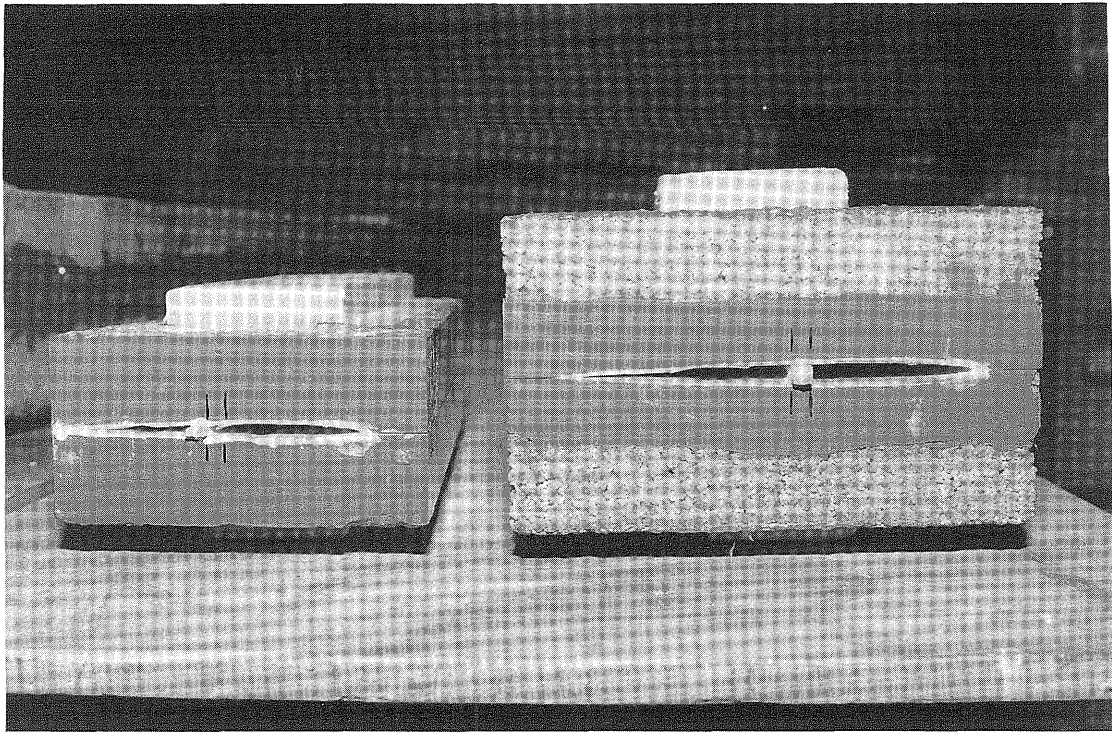


Figure 35: Horizontal tail molds containing the finished surfaces. One roofmate spar is used to separate the top and bottom sandwich skin halves.

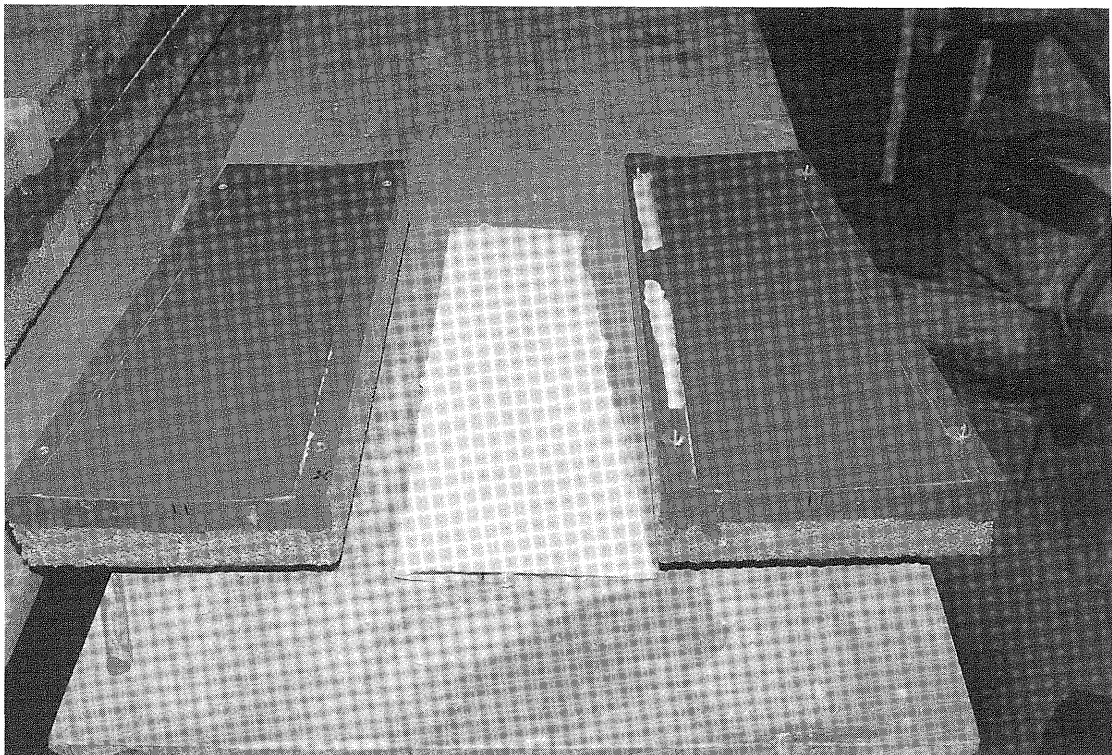


Figure 36: A finished horizontal tail section with both mold halves.

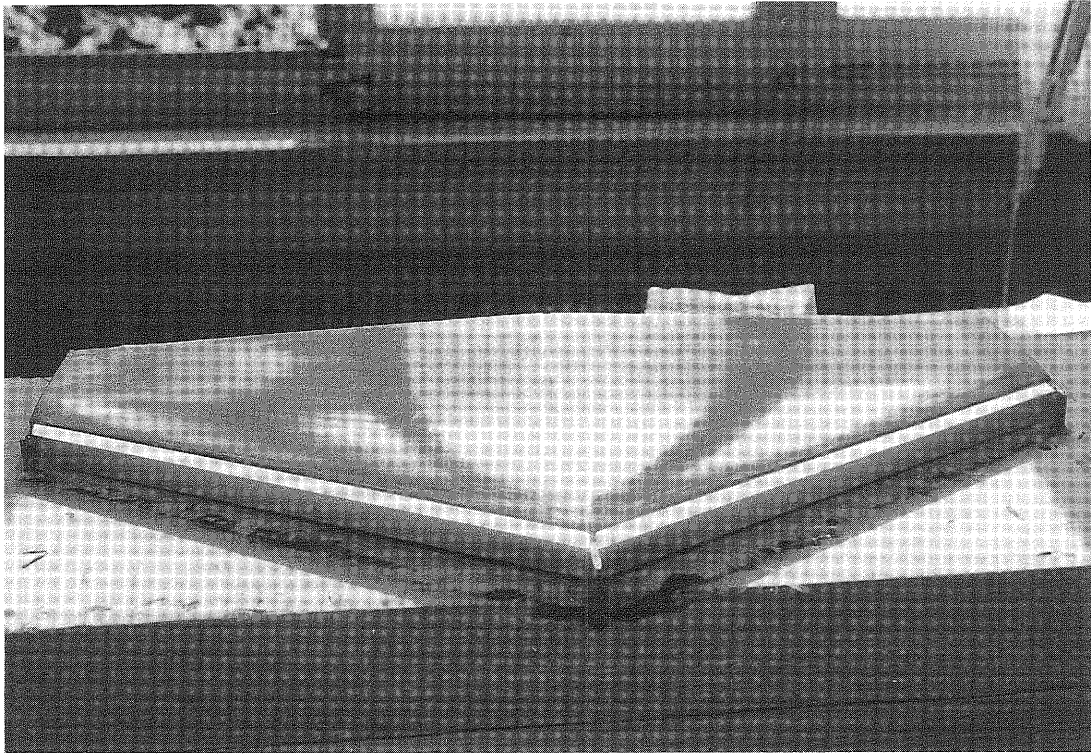


Figure 37: The vertical stabilizer section (including the rudder) is built the same way as the horizontal tail sections. This positive mold pattern is cut in half (top to bottom) and subsequently attached to the fuselage plug.

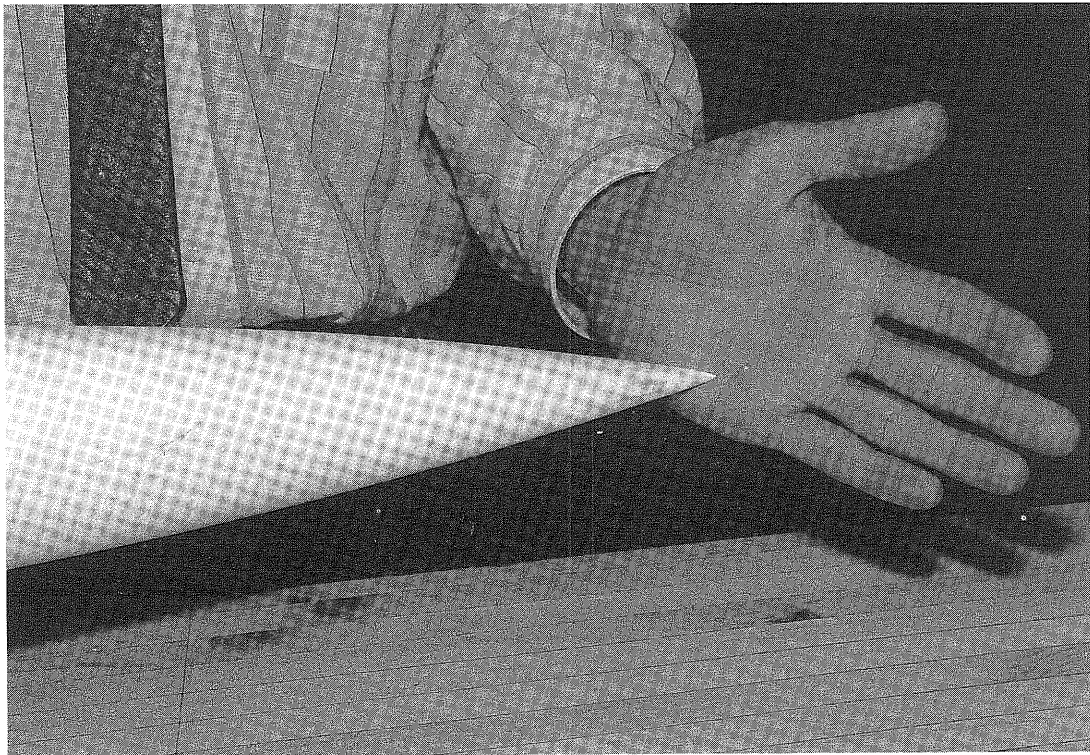


Figure 38: Tip section of the "Speedo '87" master mold and fuselage. (Useful no doubt for stopping the plane on slippery snow covered hillsides - ed.)

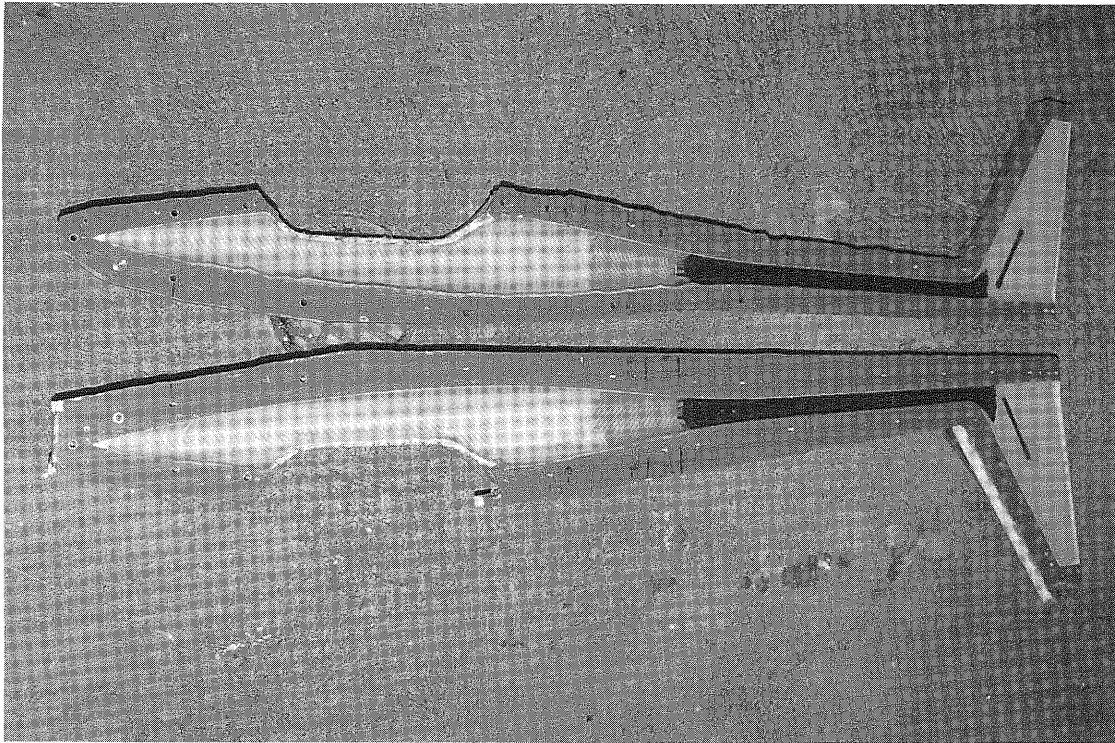


Figure 39: Laid up "Speedo '87" fuselage prior to joining molds. The light sections indicate the use of Kevlar cloth, and the black areas are carbon fiber.

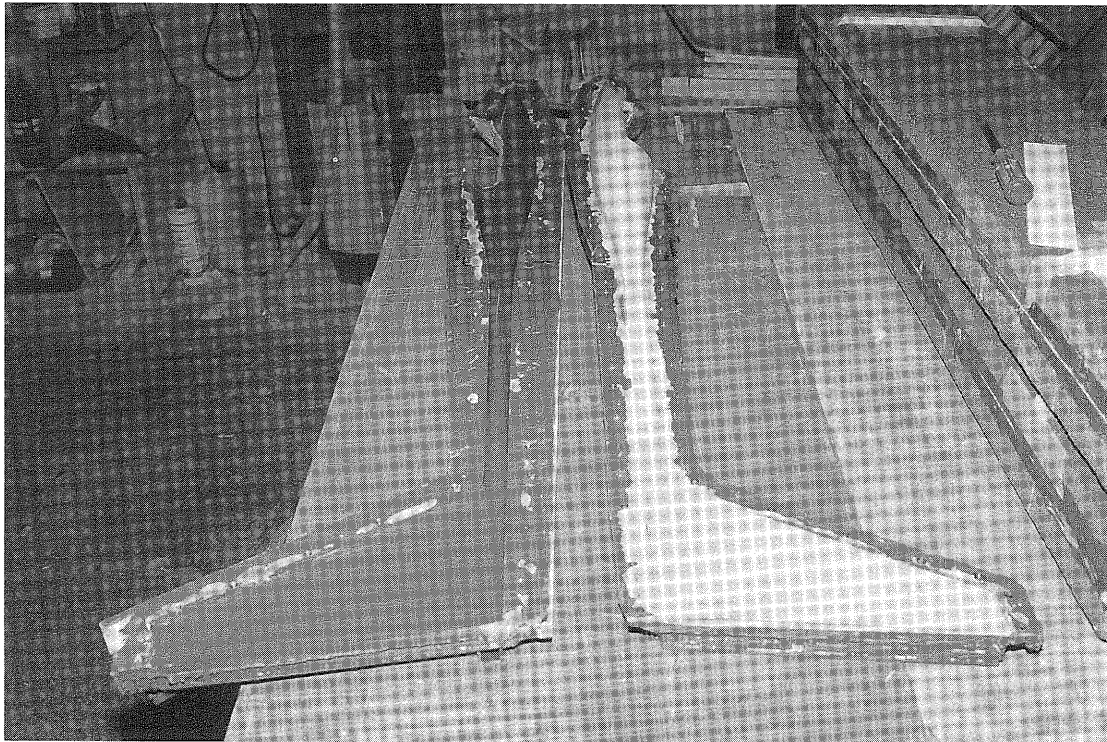


Figure 40: Giving birth or de-molding of a "Speedo '87" fuselage.



Figure 41: Parts especially molded for the "Speedo '84 and '87" projects. The plastic bottles on the left contain the LF epoxy resin and hardener. The metal can on the right contains R+G liquid wax separating agent and the can with the white cap is R+G sprayable release agent used for hard to get to corners which is especially useful for the small lever molds.

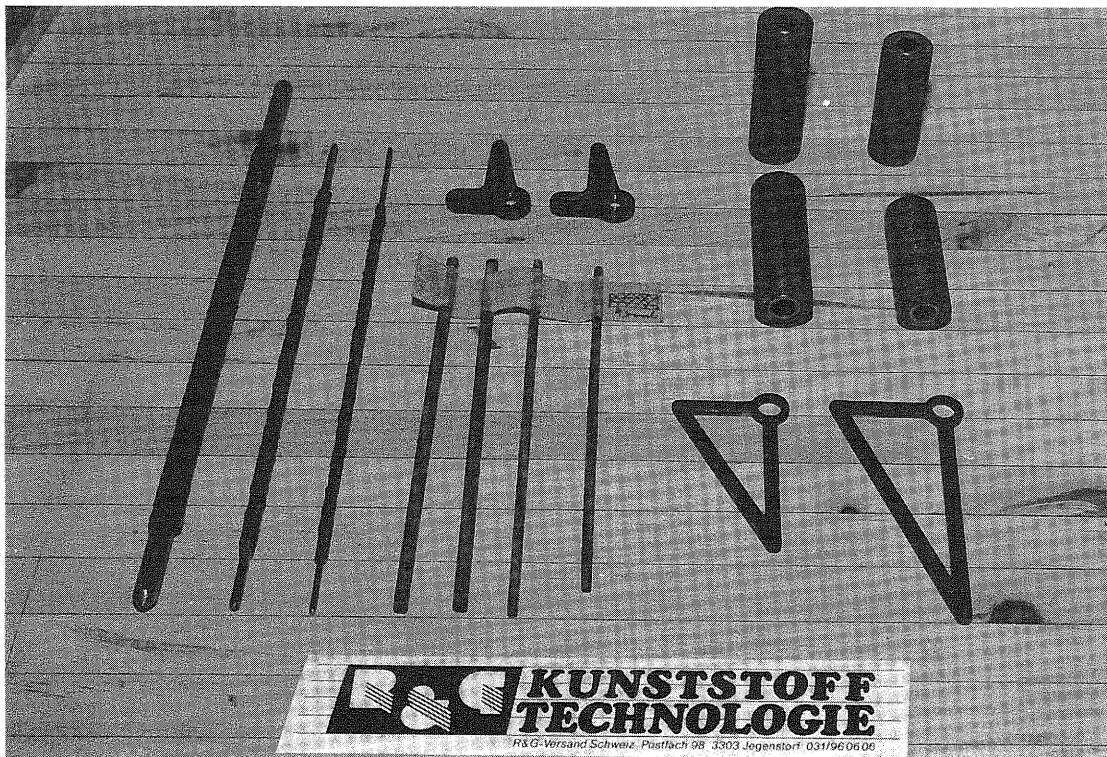
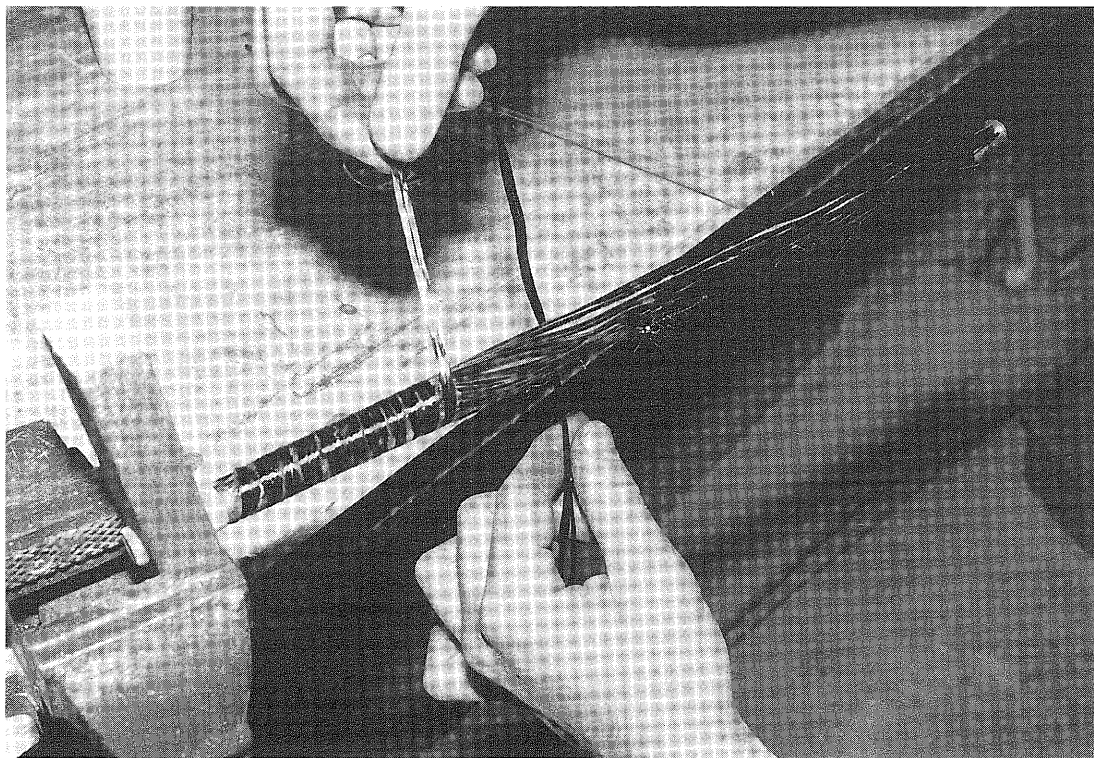
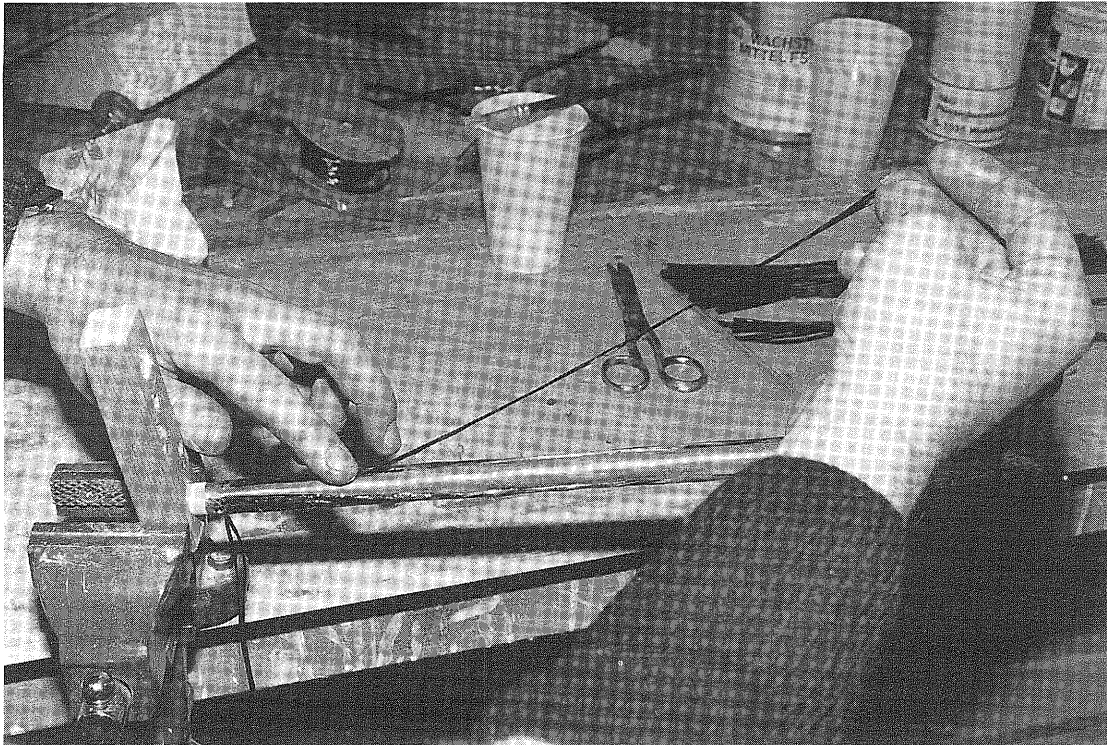


Figure 42: Carbon tubing, elevator levers, twisting bellcranks as well as centerpieces accommodating the roller bearings. These parts have to be custom made for tight and accurate fits.



Figures 43 and 44: Making of a carbon fiber centerpiece (wing joiner rod) accommodating the 6 roller bearings. Using carbon fiber saves about 50% of the weight of a steel piece.

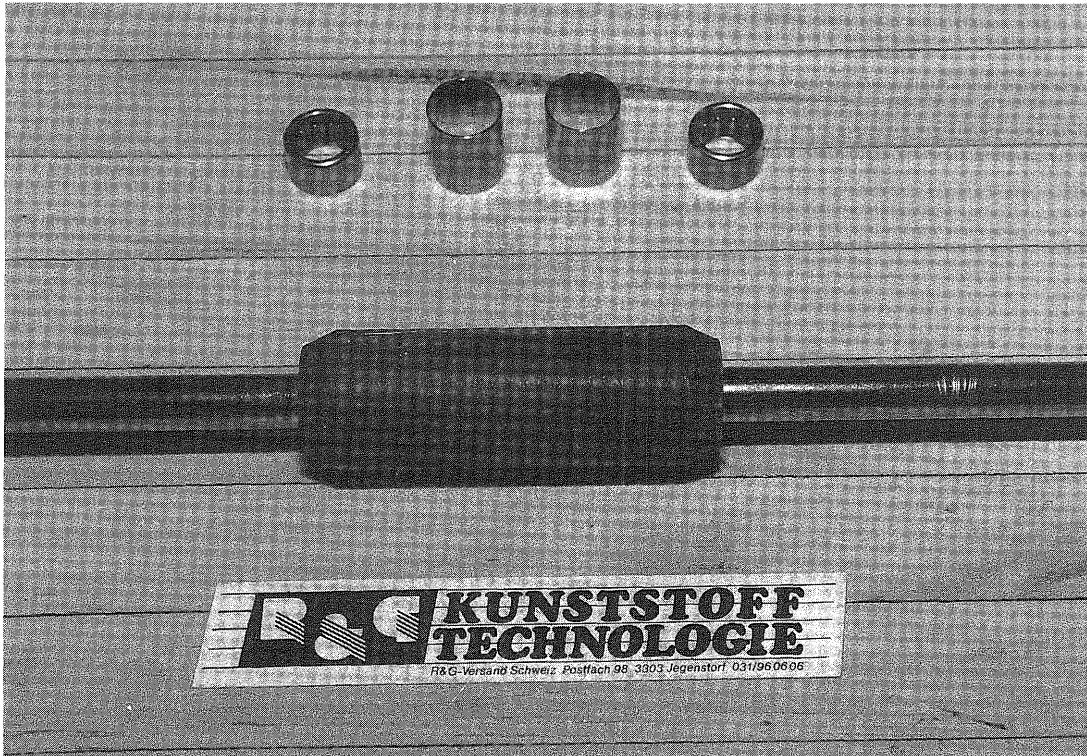


Figure 45: Machined carbon fiber centerpiece with the wing joiner rods, two roller bearings, and two spacers are in the background.



Figure 46: The elevator lever mold; each consisting of four main parts. This has been machined and milled from aluminum and steel.

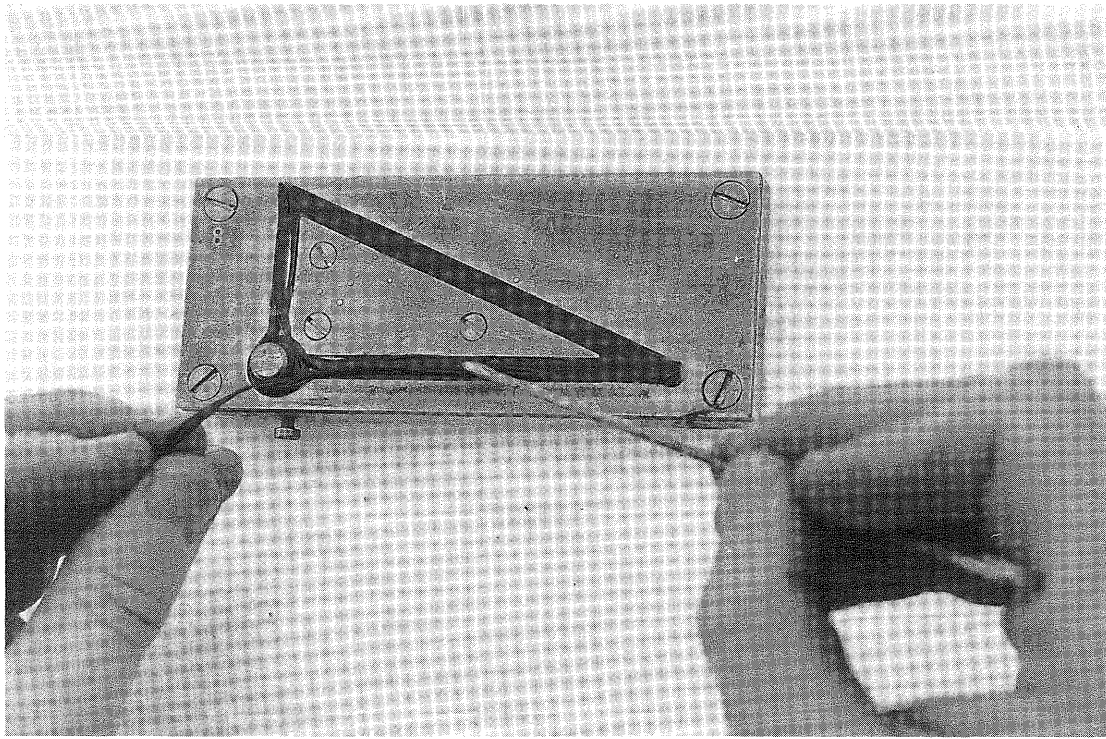


Figure 47: The epoxy resin soaked carbon fibers are placed in the assembled elevator lever mold.

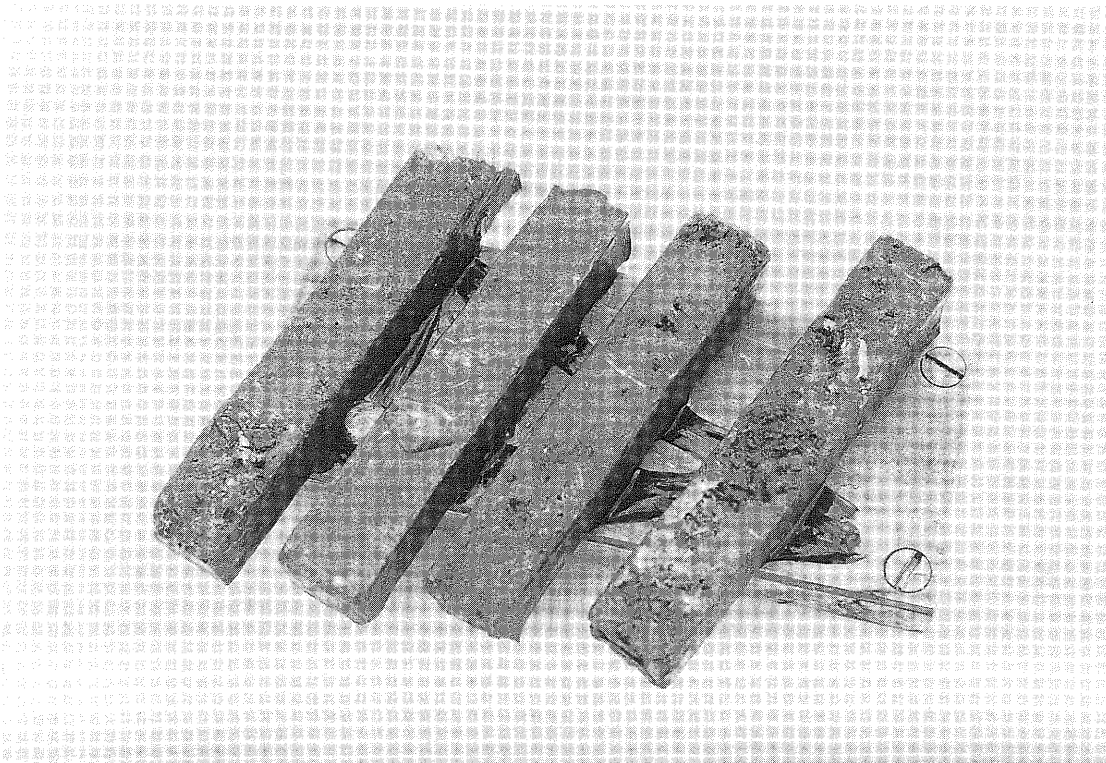


Figure 48: Lead weights are used to press the carbon fibers into the mold as the resin cures

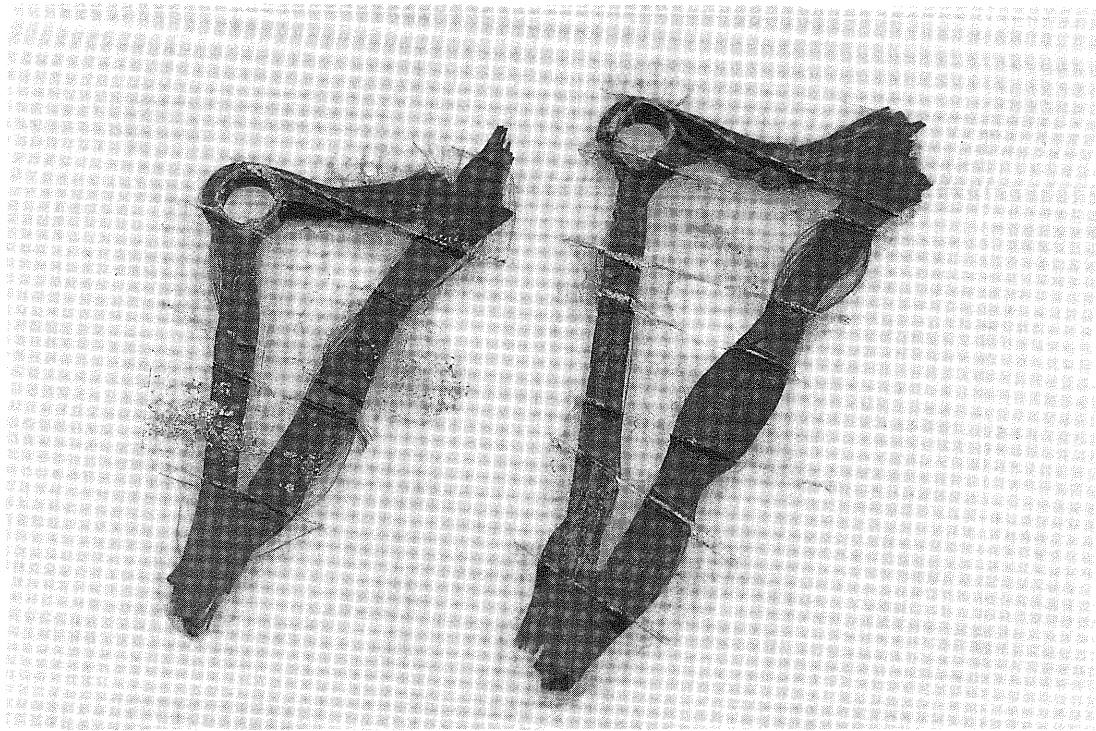


Figure 49: The elevator levers after removal from their molds. The rough appearance of these is caused by excess resin and carbon fibers which are later sanded away to yield the finished units.



Figure 50: The elevator molds with their respective finished levers.

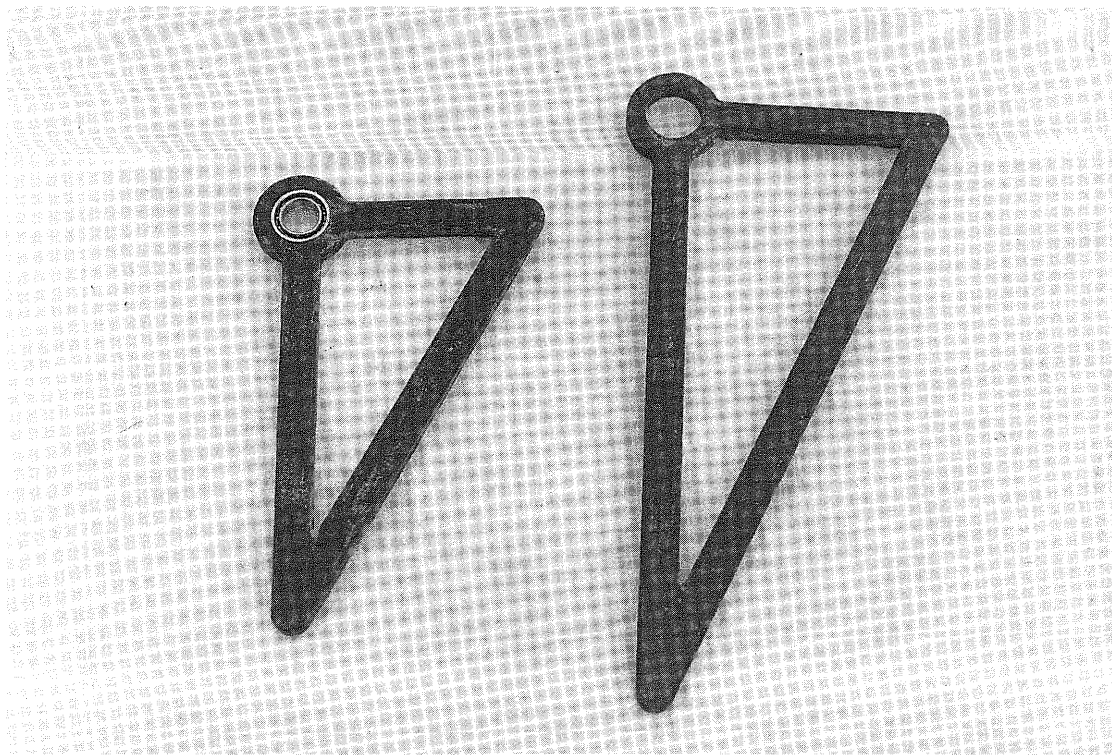


Figure 51: Ready to install the elevator levers. they were designed to accommodate a small ball bearing to guarantee minimal play and low friction.

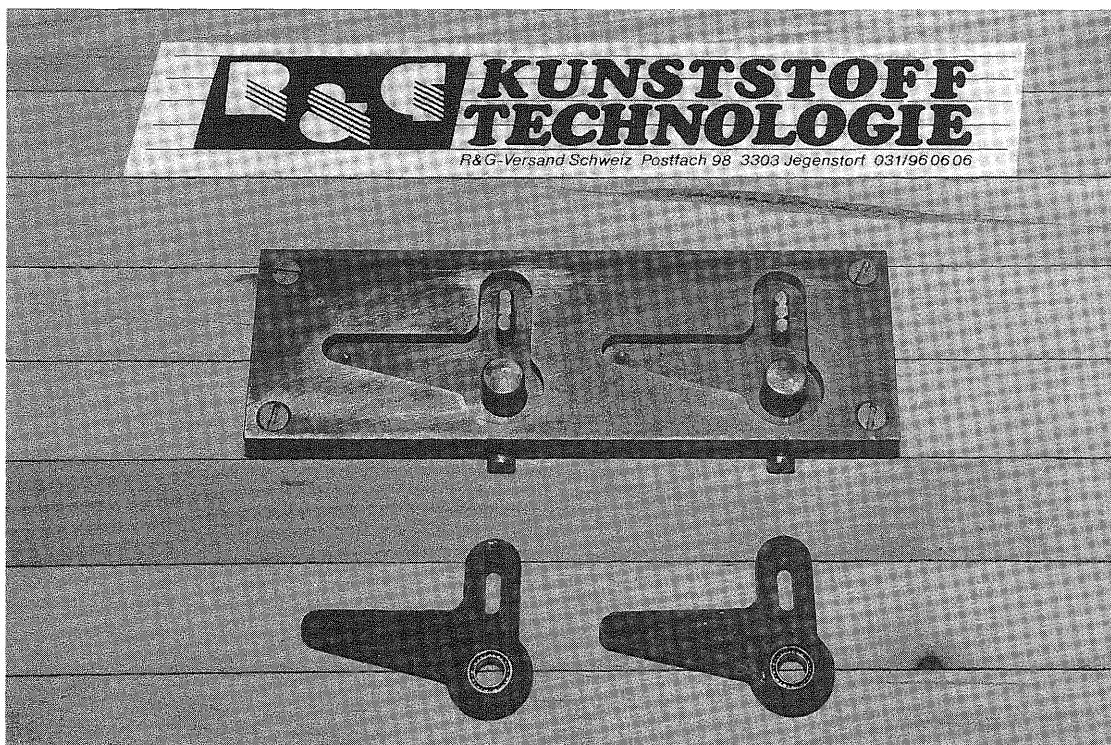
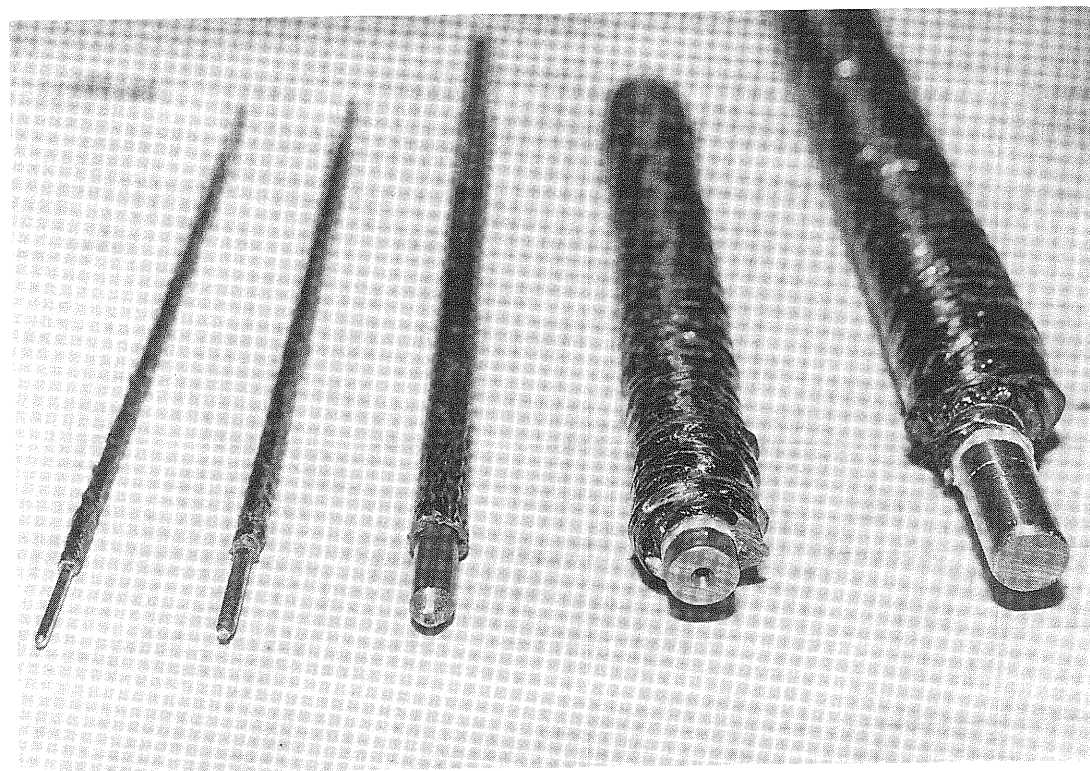
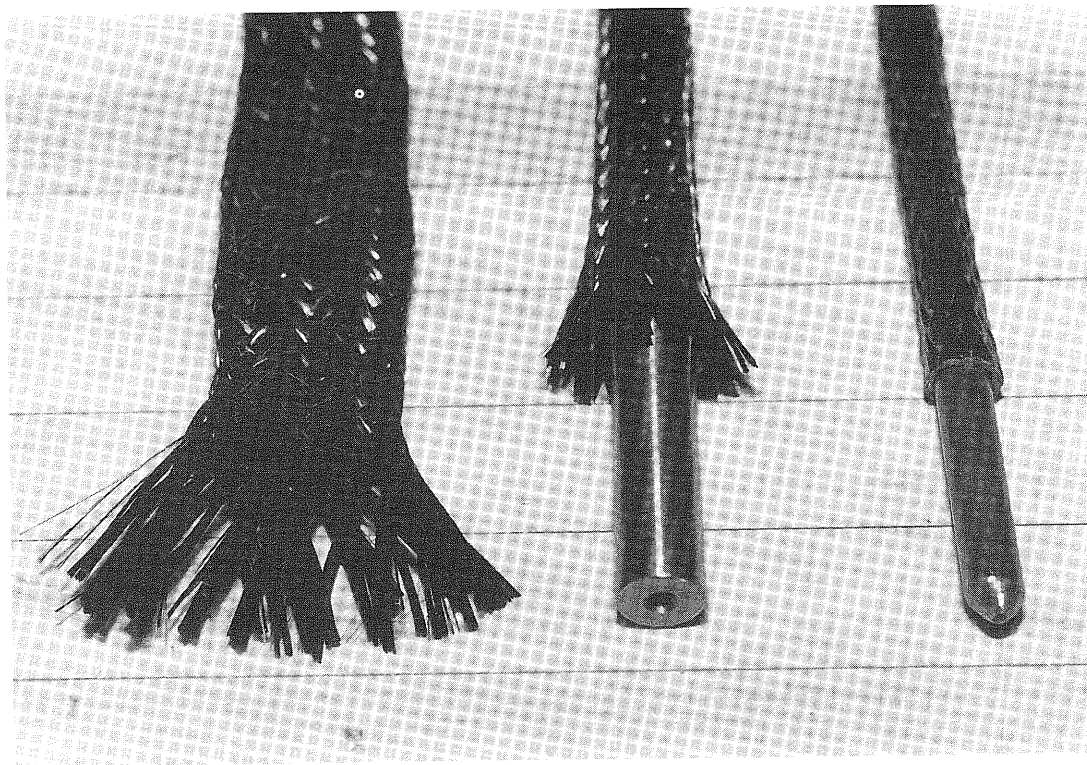


Figure 52: the mold with carbon fiber bellcranks used for the wing twist control system. Each lever accommodates two ball bearings.



Figures 53 & 54: Carbon fiber tube cloth is used to make tubing that is both light weight and tight fitting. The steel centerpieces, which serve as molds, are treated with wax based release agent before being covered with the epoxy soaked carbon tubing. After removing the steel centerpieces, the remaining carbon fiber tubes are used in place of brass or aluminum tubing in the aircraft construction.

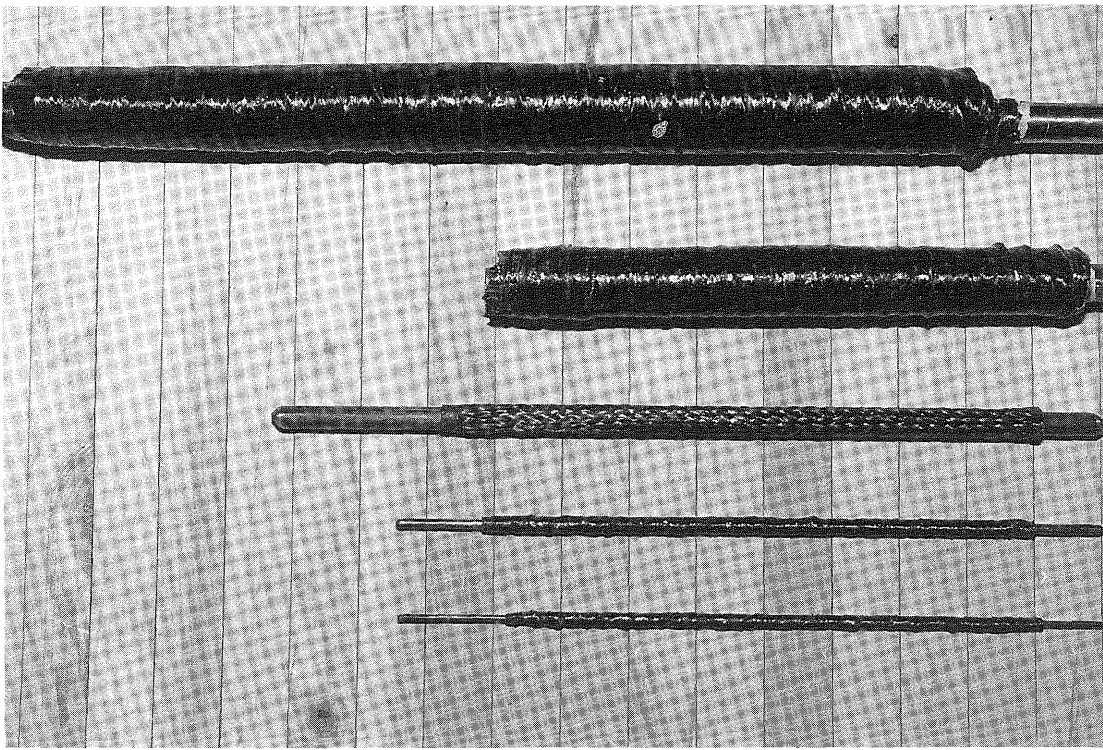


Figure 55: A lineup of several sizes of the carbon fiber tubing.



Figure 56: Martin Bamert's workshop in which the "Speedo '87" was designed and built.

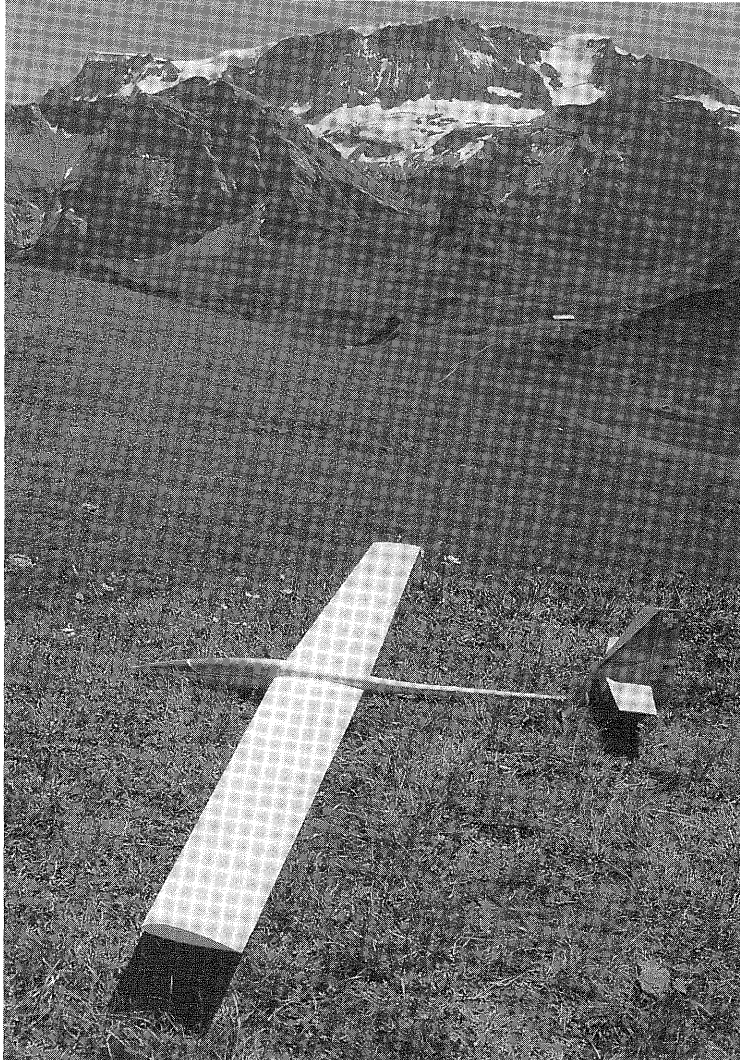


Figure 57: "Speedo '87" pictured at the Lavey ridge which is 6900 feet above sea level. Lavey ridge, Schalmi ridge and Metschstand are located close to the Hahnenmoospass region of Switzerland. The area is surrounded by the beautiful Swiss Alps. In the background, the 10,641 foot Wildstrubel accentuates the beauty of this glider paradise.

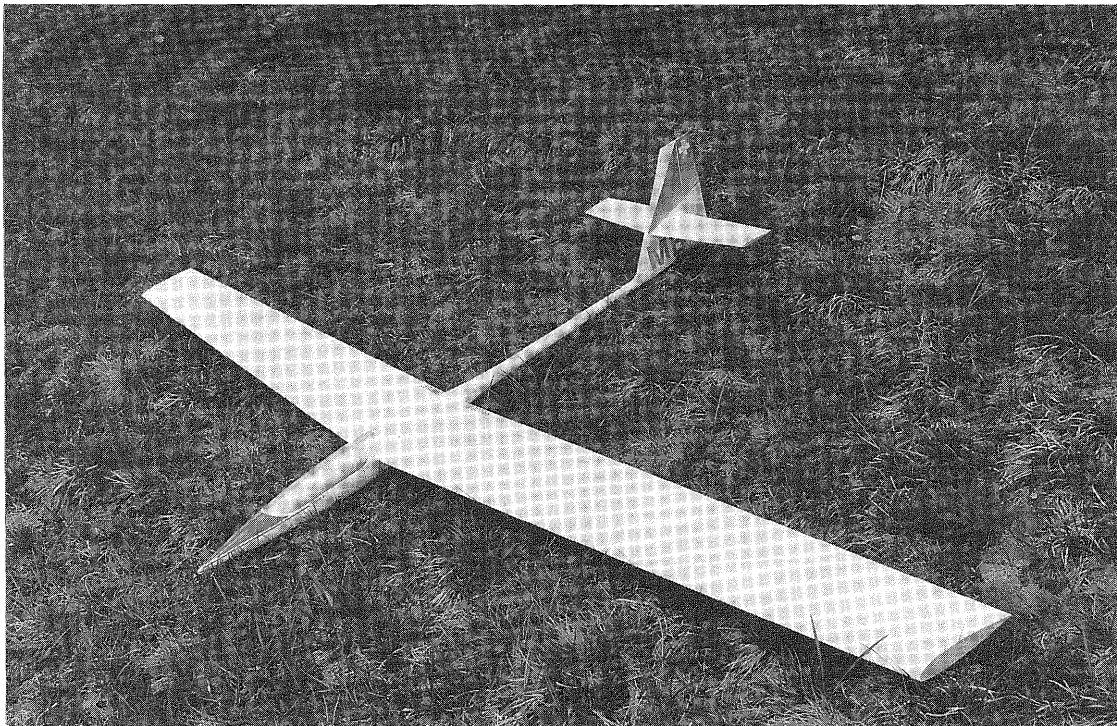


Figure 58: Full view of the "Speedo '87".

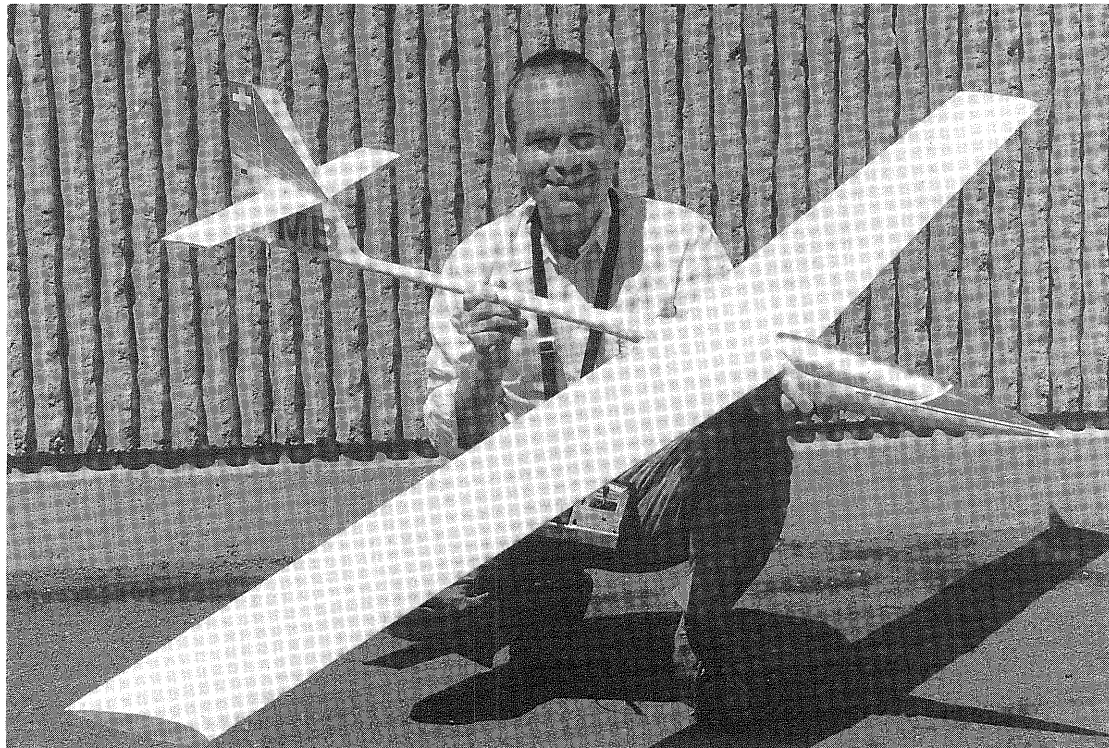


Figure 59: Close-up of a younger Martin with "Speedo '87".

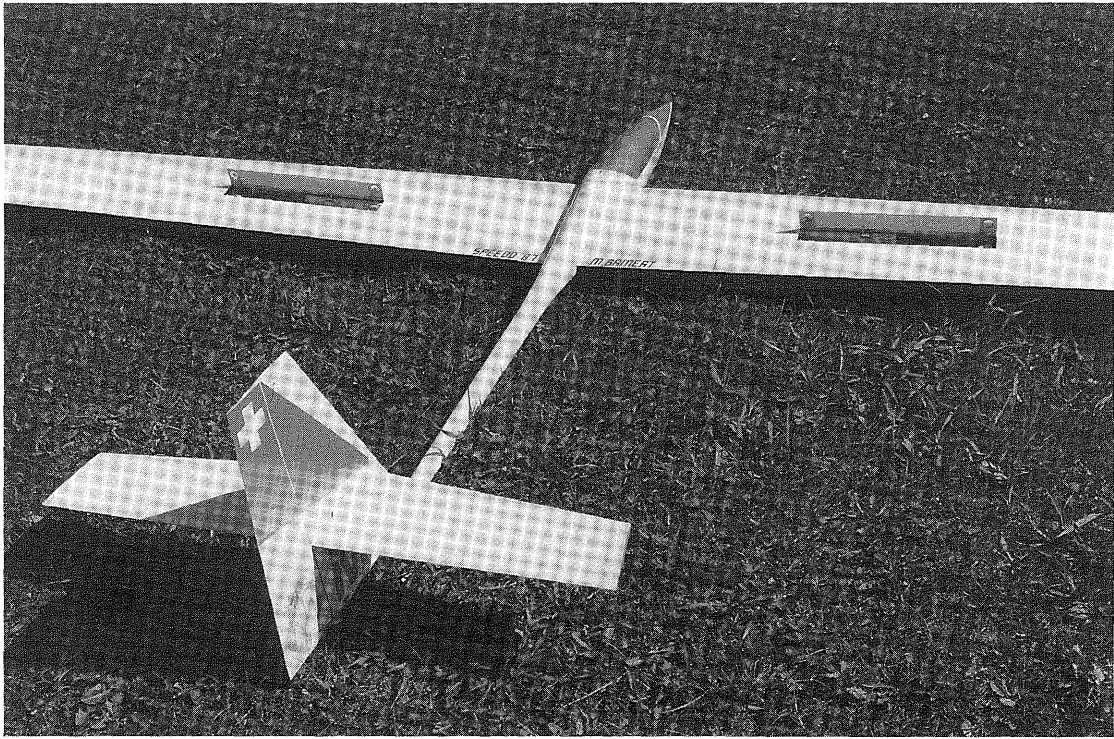


Figure 60: "Speedo '87" with deployed airbrakes. A small amount of up-elevator has been mixed into the airbrake function to prevent a sharp nose-down effect when they are deployed.



Figure 61: Another take off at the Schalami - Ridge, one of the best slopes I have ever flown at. The wind blows close to vertically up the ridge to provide excellent lift.

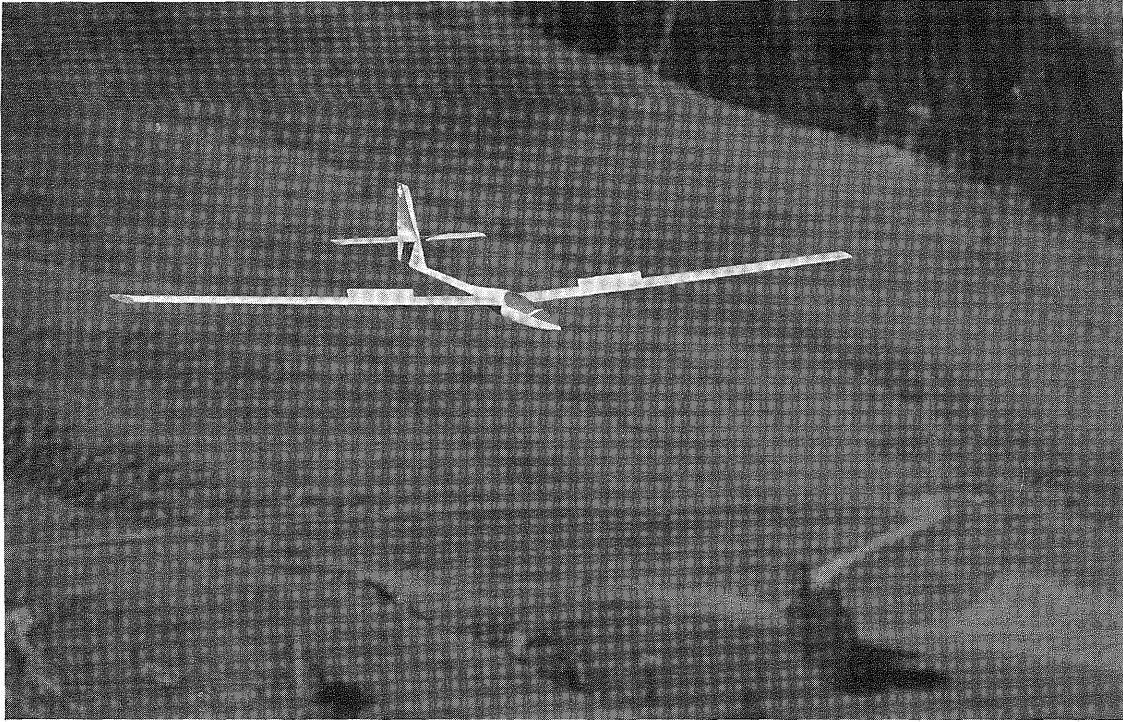


Figure 62: Low pass with deployed spoilers.

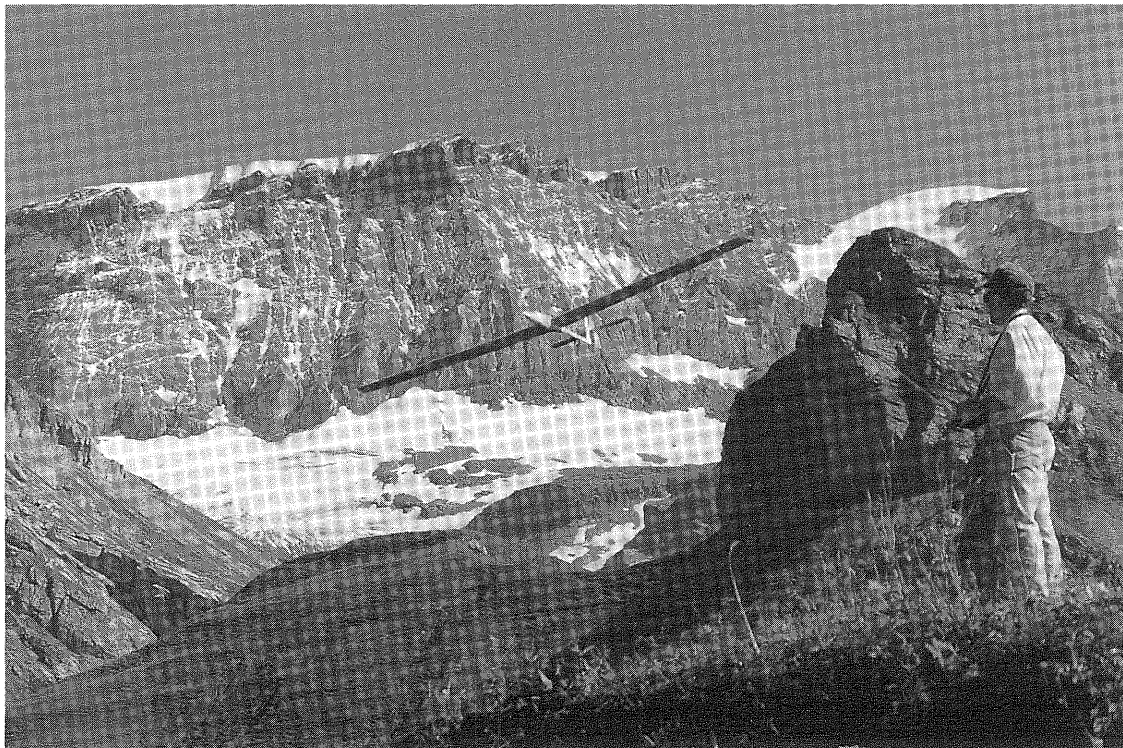


Figure 63: Low pass in front of the pilot.

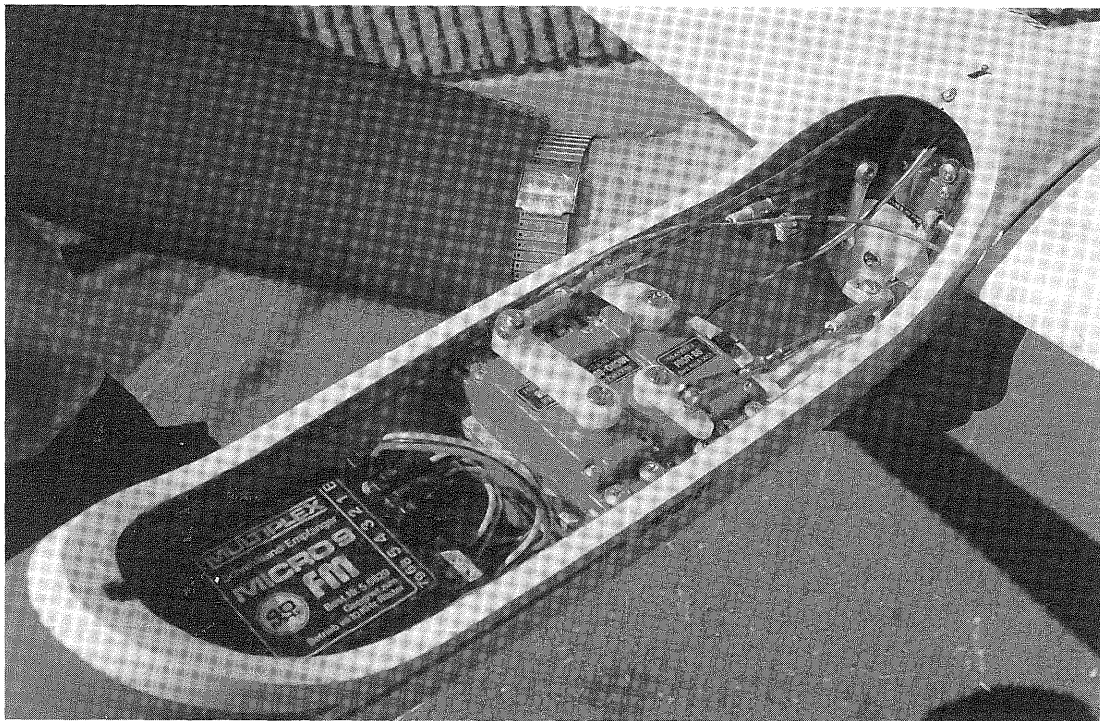


Figure 64: View under the canopy. The RC controls include twist wing (ailerons), elevator, rudder, and spoilers. Mixing the twist wing design to produce both aileron and elevator control has not been attempted. Flying through rough turbulent air at high speeds and especially during hard landings can apply tremendous forces to the twist wing servos. This effect is prevented by using one 70 ounce-inch servo to provide the push-pull forces for both wings. This tends to cancel the forces feeding back from the wings. The maximum angle to which the wings twist is limited to plus/minus 4.5 degrees.



Figure 65: Slow pass above the lift-producing valley.

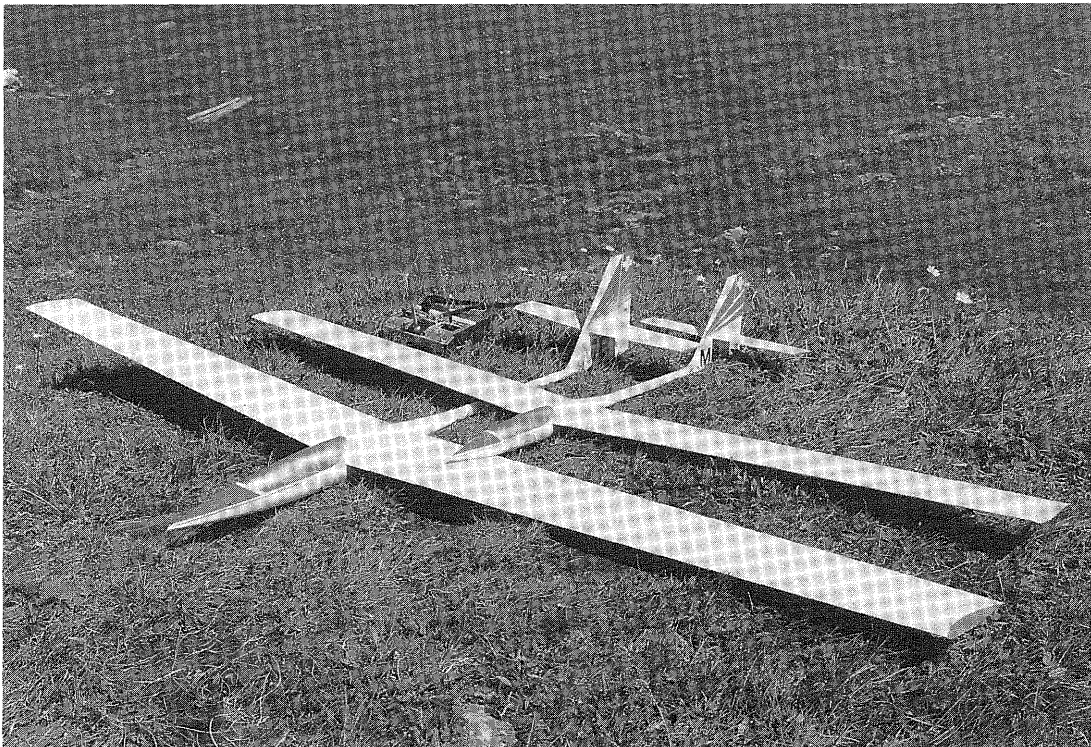


Figure 66: Size comparison of the "Speedo '87" (front) with 2.4 M wingspan and the "Speedo '86" with 1.97 M wingspan. the "Speedo '86" is really a "Speedo '84" which was built in 1986

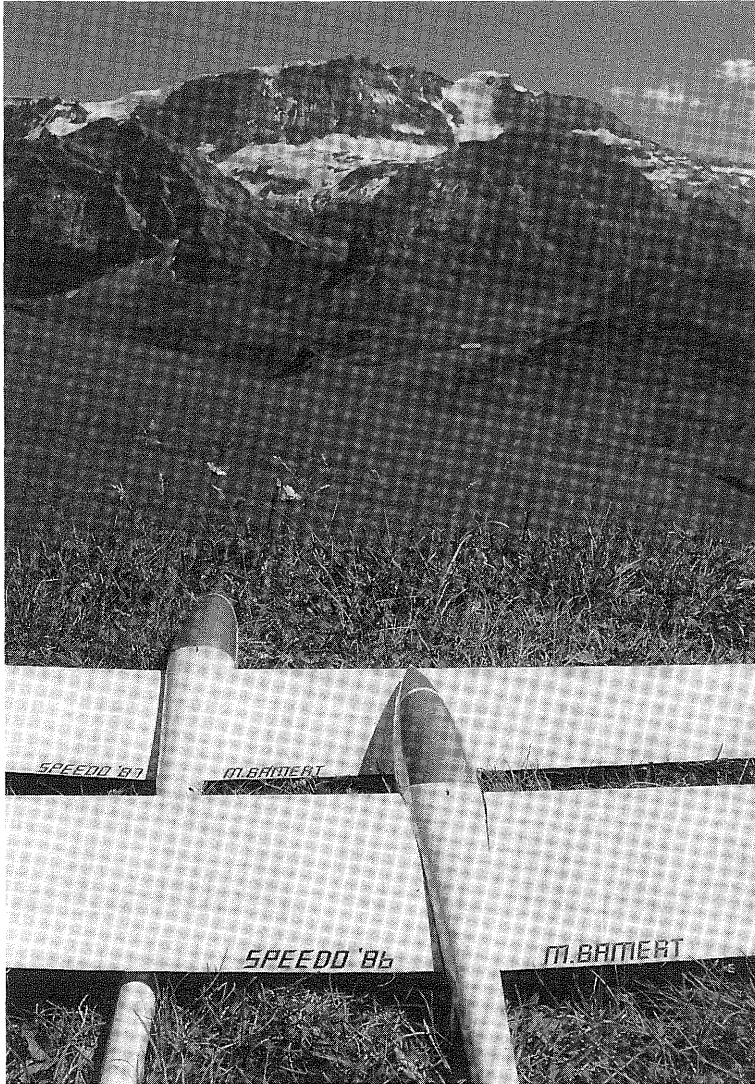


Figure 67: Waiting for flight!

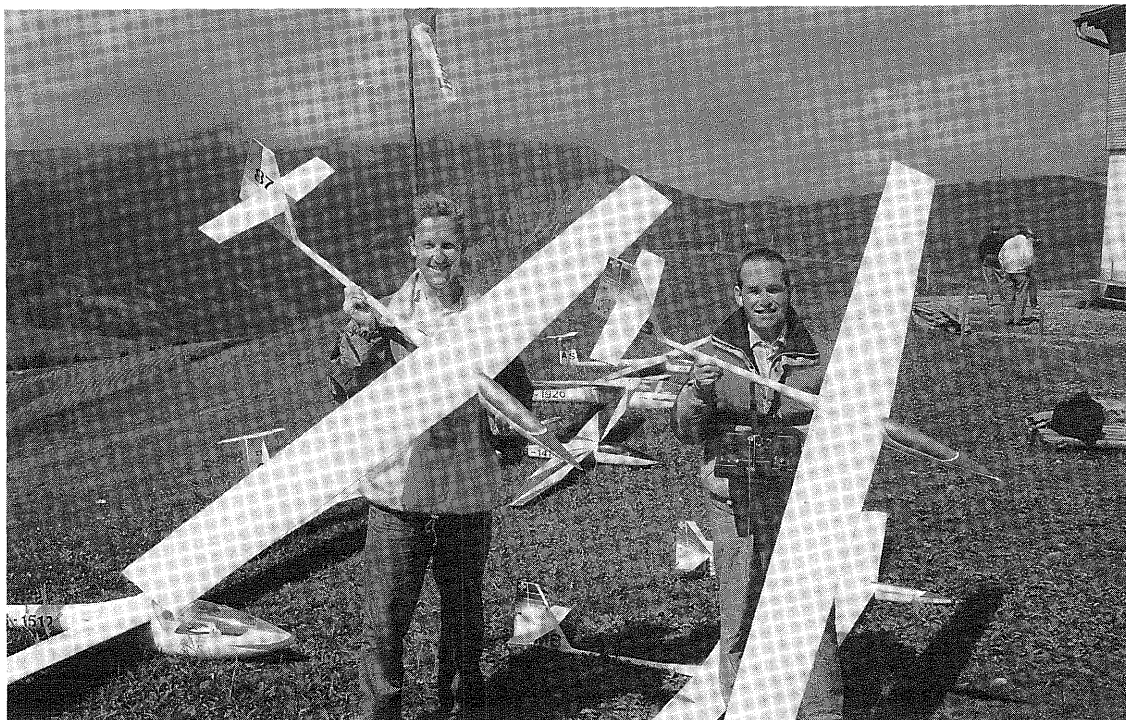


Figure 68: Jürg and I with two "Speedo '87" high performance gliders at the base of Glider Paradise; Hahnenmoospass!

All photos have been taken by Martin Bamert, Rolf Bamert, or Jürg Wermuth.

VISION AND SOARING by Herk Stokely

This article was published in "Silent Flight" magazine issue dated February/March 1993. "Silent Flight" is edited by Dave Jones, and is published by Argus Specialist Publications, Argus House, Boundary Way, Hemel Hempstead, Herts. HP2 7ST England. It is reprinted here with the permission of the publisher. The copyright for this article is the property of H. A. Stokely and Argus Specialist Publications. No reproduction is permitted without prior consent from both parties. For non-commercial publications, you may assume that you have my permission, but it should be cleared with Argus first.

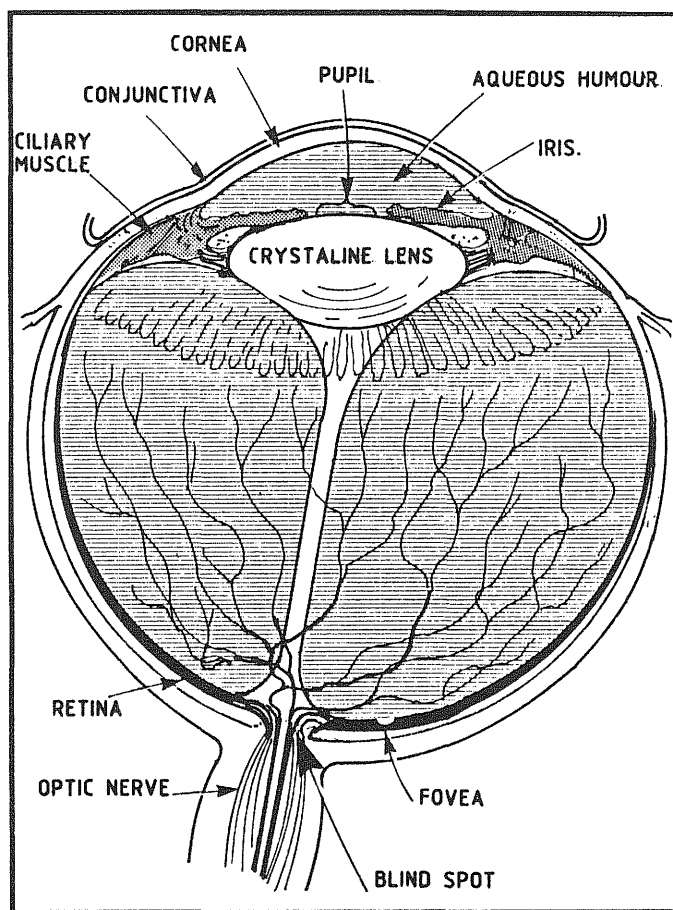
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SPECIAL

**Herk Stokely
discusses vision and
how to improve it**

Soaring, and indeed any type of flying is a visual sport. Without vision, we'd have the feel of the wind, and the smell of the outdoors, the heat of the sun, and perhaps the sound of a passing model, but it is an activity where vision is the central and only really significant element. I've found that many people accept rather poor vision as completely satisfactory, and others with "good vision" or even "perfect vision", have very scant knowledge of its limitations, and no real understanding of how the effectiveness of good vision can be improved dramatically.



eyesight & soaring

The problem

Small images in a big empty visual field are the main problem that our vision system has to deal with. I have a good autofocus video camera, and I've noticed that it needs some fairly sizable image with sharp lines to focus on. I've used it quite a bit for aviation and model flying subjects, and found that it has real problems when it has to focus on small images in a low light or low contrast. Sometimes the focusing system will just start to search back and forth, even passing right through correct focus without stopping. Under similar conditions our eyes will tend to do exactly the same thing.

Some years ago, I was flying US

Navy tactical jet aircraft. This was a time when our tactics, without the benefit of search radar systems, required us to locate other aircraft visually. As a fairly young pilot, with very good (maybe even perfect) vision, I was dismayed by the ability of our "older" training officer to consistently find other "traffic" long before I could. When I asked him how he did it, he put me off with "You won't see them if you don't look!". Realizing that he might not know, himself, how he did it; I took the engineer's approach, and found a book.

"Problems of Vision at High Altitude", by T.C.D. Whiteside seemed was the answer. It was published in 1957 by Butterworth's Scientific Publications of London,

and dealt very precisely with my frustrations. I learned a lot from that book.

It very clearly revealed that there are some challenging problems for the best of eyes when their task is seeing small objects at long distance in an empty sky. As a Navy pilot my main concern was to see other airplanes at long distance. (In other words; before they saw me!) I've learned even more since my eyes (which used to be perfect) got into their forties. I'm only 39 of course, but my eyes have lived a fast life!!

The problem with our eyes comes from the fact that nature equipped us to give highest priority to moving objects in our immediate surroundings. We have been given eyes that focus automatically on the objects of our attention, but when we look into a blank visual field, like an overcast or clear sky, our visual mechanism goes into what I call "Parade Rest". What I mean is; for each person the eyes focus at some "rest" distance. Dr. Whiteside's studies and tests showed that when looking into a completely blank visual field, the eyes of people with completely normal or "Perfect Vision" will usually automatically settle into focus at about ten feet.

That's far short of the distance to our sailplanes when they're way out or high up in a featureless sky, but

it's not as bad as it seems. In bright light normal eyes that are focused at ten feet will still see objects in fairly sharp focus on out to infinity. Bright lighting gives eyes (and cameras) excellent "depth of field". To see a small sailplane at great distance however, we need more than "fairly sharp" focusing, and many of us don't have perfect eyes! With some degree of near-sightedness that "rest focus" might be more like the distance to the end of your nose! An older set of eyes with a bit of normal, age related far-sightedness, may not "rest-focus" with clarity at any distance.

Whiteside's book indicated that for a long time the standard concept was that with normal vision, the relaxed eye would focus naturally at infinite distance. If it was true, it would be perfect for sailplane flyers. His studies however, revealed that this is not correct. Apparently there is a natural amount of tension in the ciliary muscle that causes it to focus naturally at about ten feet instead of infinity as expected. Dr Whiteside called this "Blank Field Myopia".

I can't begin to summarize all of the data I found in Whiteside's very comprehensive analysis, and some of it isn't even applicable to model flying. There are however, three very important points I will make.

The pupil

First is the role of the pupil in focus. The principle is simple. The smaller the diameter of the opening at the front of the eye, the easier it is to focus at any distance. In fact the simplest of cameras is a box with no lens - only a pinhole, and it is essentially in-focus at any distance. The reticle sight (or peep-sight, a disk rear sight with a small hole in its centre) of a rifle takes advantage of this effect to put both the post on the end of the rifle barrel and the distant target into clear focus at the same time. The pupil of our eye closes to a small diameter in bright light giving us excellent depth of field regardless of where the eye lens is focused. This is great for model flyers who usually fly in bright light, but much of its benefit is lost when sunglasses are used.

Focus

Second, when a small object is even slightly out of focus, it is twice as difficult to see as when it is in focus. That means that if you lose

your distance focus on a model flying far away, you can't pick it up again till it is about half the distance where you lost it. In other words, the model has to appear to be twice as big as it was when you lost it. Our visual system needs sharp edges in order to focus, and even slightly blurred objects do not have visually sharp edges. This chart (below) from Whiteside's book shows that effect very dramatically.

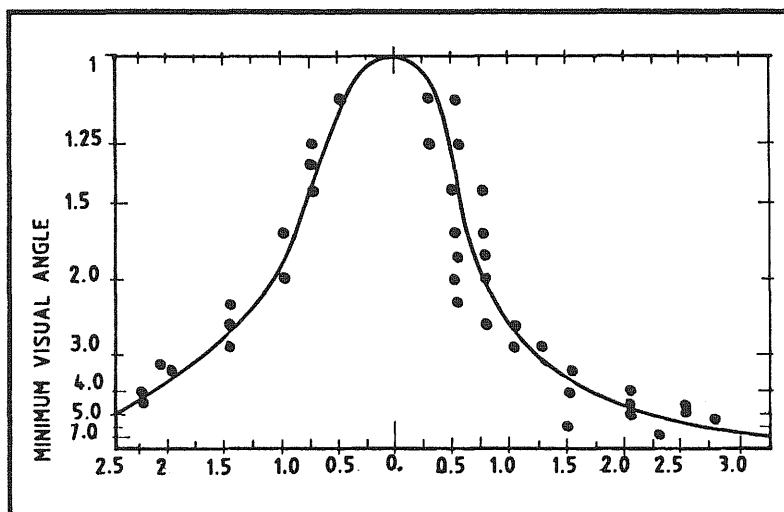
The vertical axis is the apparent size of the target in degrees of visual angle. For a target of fixed size, twice as big is half the distance. The horizontal axis, in diopters, is a measure of the amount of blurring effect from being out of focus. The more out of focus the object, the more blurred it is, and the bigger it has to appear before you can see it at all.

Third, even with correct focus and a sharp image, the area of our visual field that is effective in seeing small

angle in degrees from the centre of the fovea (the central vision point of the eye).

You might be asking why I'm going into all this detail, so here's the bottom line. When you look into a blank field with no visible object to set the focusing mechanism, your eyes will try to refocus automatically in a very short time. If you look away from your model, or momentarily lose sight of it as it turns, the empty sky can cause you to lose your focus making it almost impossible to find it again. We often fly that far away, and anyone who has gone to the limits knows that panicky feeling when you look right at the spot where you know the plane is, and you can't see it.

Fortunately we can take advantage of the fact that the focus system doesn't change instantly. Once you've lost distance focus you can reset your eyes by looking to the nearest clearly visible object that is



objects clearly is only about two degrees wide. So, even if you've solved the focus problem, you still must look directly at the model to see it when it's far away. Another very dramatic chart (see overleaf) clearly shows this effect.

The vertical axis in this chart is presented differently, but it amounts to the same thing. If a small target isn't near the centre of your vision, you can forget about being able to pick it up as you search. If you miss by just ten degrees, the target has to be five times bigger before you'll pick it up. The horizontal axis is the

about the right distance away. It has to be something fairly large and it must have some sharp edges. A friendly nearby cloud with a sharply defined edge is the best bet. Murphy's Law however says that there won't be one there when you need it. The horizon is usually around (pun intended) and it, or a tree, or building at distance makes a good subject. Another model in the sky is also a great help. Look quickly to the nearest sharply visible shape, and give your eyes a second to focus clearly on it. Now quickly shift your gaze back to the place where

the model should be. Try to do that without blinking. If you don't pick up the model right away, go back to your reference object and refocus before trying again.

Optimising your eyes

This is a poor system for picking up a lost model. It's moving, and finding it in those first few seconds is critical. The fact that we have to look right at the model's position (within about two degrees) makes this task very tricky. If you really want to fix the problem, even if you have perfect vision, you can benefit from corrective glasses that keep your eyes focused on distant objects even when they are at their "empty field" state of normal tension. With such a set of optimized lenses, you

have all of the problems I've been listing. The optometrist may tell you that his testing room with the eye chart 20 feet away (or even closer) is OK for setting your eyes for long distance. Don't believe it. Make him tweak that prescription till you can see the individual leaves on the top of a tree a quarter mile away. My eye test involves walking outside with the initial prescription, relaxing my eyes, and looking at distance objects as the optometrist moved in and out additional corrective lenses, till we found the combination that made the most distant objects clear and sharp.

You have a role to play in all of this too. Focusing isn't normally a conscious reflex. You have to practice allowing your eyes to find their relaxed normal. It's that out of

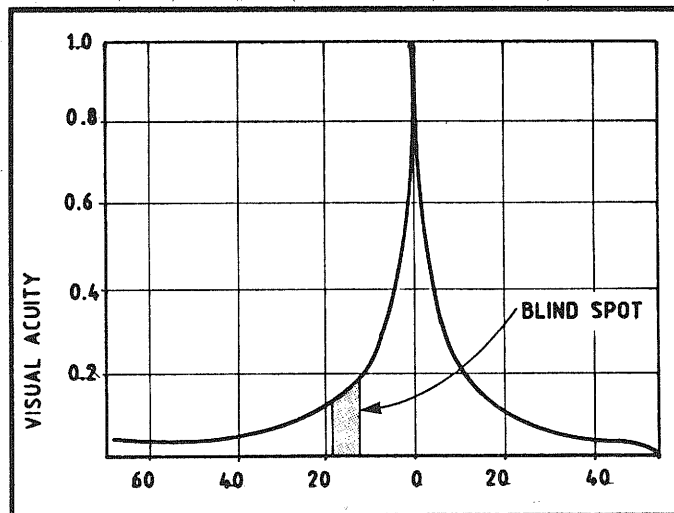
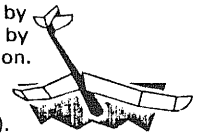
when you are rigging or adjusting your model. Add a bi-focal lens to the glasses that is optimized for the kind of arms-length distance you use when doing normal close up work at the flying field. You'll find that such a set of sun-glasses are perfect for driving and full scale flying too. The upper lens is perfect for the distance and the bi-focal just right for the instruments and map.

The fact is, that older eyes may benefit from this process more than the younger. The lens of the eye is one of the tissues of the body that continues to grow. As we age, it gets thicker and stiffer until the focusing muscle has little effect. Even strengthening the muscle with exercises is little use, as the lens is suspended from the muscle by fibres. The system relaxes the lens when the muscle tightens, and overtightening the muscle just lets the fibres go slack. An older person's eye is more likely to resemble a fixed-focus system with little automatic focusing possible. Since it is fixed, the use of auxiliary lenses almost guarantees that the desired focus will be there. Young eyes are always busy looking for the right focus and may not settle in where you want them to; no matter what kind of lenses you use.

However, you manage the focus problem, the narrow cone of central vision is still a problem. With only a couple of degrees of clear central vision to find a lost target, the search pattern you use has to take into account that the tiny spot of central vision has to pass over the object of your desires or you won't see it. That means a tightly controlled search pattern has to be used to find the lost model within the small cone of central vision. A raster scan back and forth across the area with small vertical shifts between scans, or a radiating spiral that gradually grows in diameter will work. Work it out in advance, and practice by looking for someone else's far out and high up; before you need it to find your own.

Whatever you do, see if a set of special flying glasses won't help you with your specific eyes, and whatever you do, keep them shielded from that blinder - Ultra-violet. (There are two other texts that are worth of study; the Psychology of Perception by MD Vernon published by Pelican Books and Eye and Brain (The Psychology of Seeing) by RL Gregory, published by Weidenfeld and Nicolson.

There are many puzzling effects explained in these, DJ).



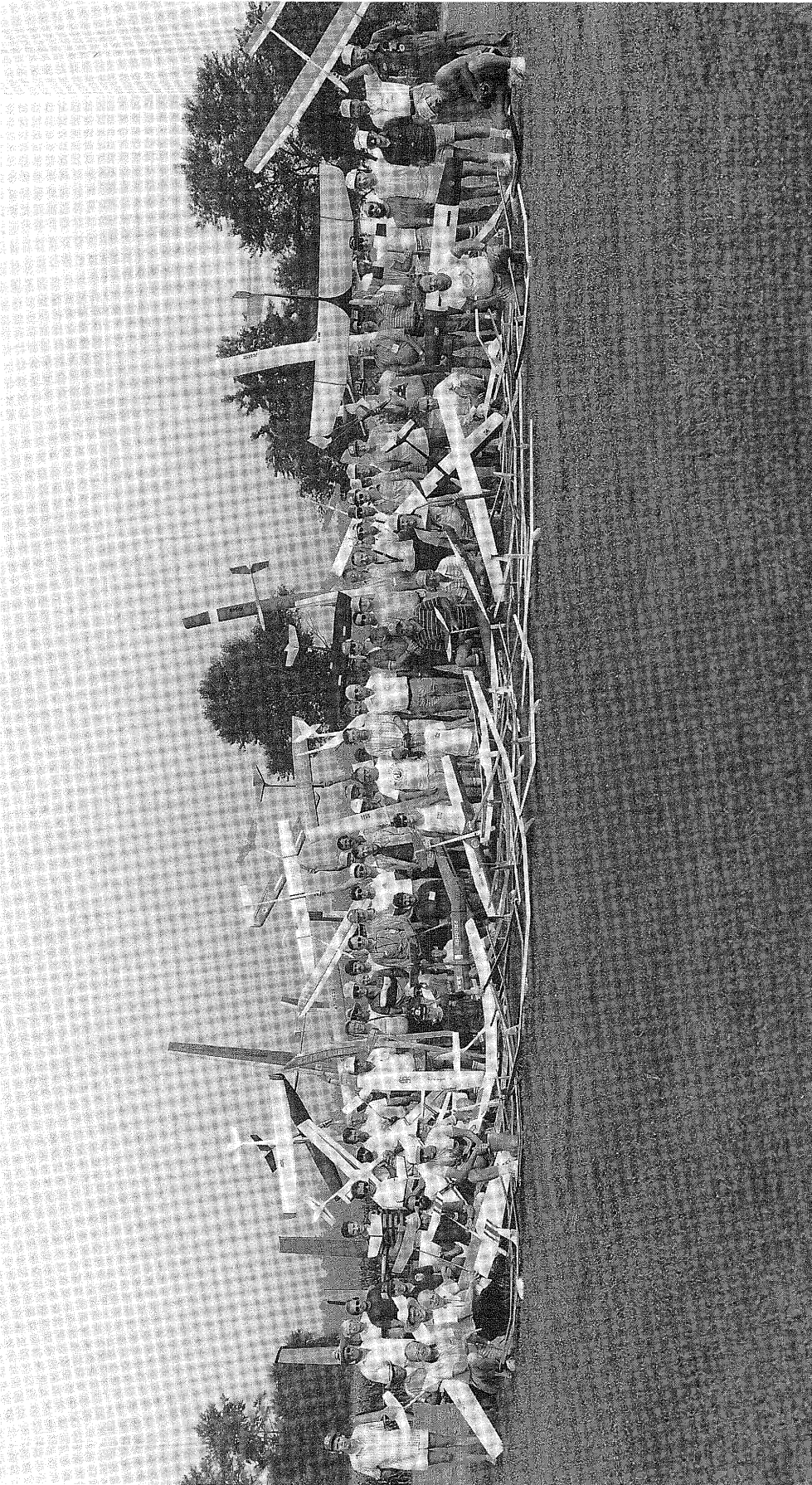
eye muscles will be at-rest and in-focus perfectly to find a small model in a blank field.

You should also see that the glasses are coated with a broad spectrum UV blocker coating. That are optimized to give perfect focus at long range. It is now well known that Ultra-violet light damages the cornea and lens of the eye, eventually causing cataracts.

It's harder than it sounds to get an optometrist (optician) to work with you till you have really optimized your visual system for long distance. Remember that our eyes go to "parade rest" when they are looking into a blank field (like the open sky). Unless that at-rest distance just happens to be correct for long distance vision, you will

focus, sort of daydream - condition that your eyes go to when you have them open but your vision is really focused on inner things. Another way of describing it is "gazing into space" as when you are tired and inattentive. Younger eyes that are constantly into focus-searching like my video camera have to practice relaxing in order to be able to take advantage of a distance vision lens.

If you have that prescription made into sunglasses The effect of pupil enlargement will be minimized. Since the prescription will help you focus clearly at distance, no pinhole effect from a tightly contracted pupil should be necessary. If you have older eyes, you may find that you can't see clearly with these glasses when you are working close-up; as



PROGRAM FOR THE CALCULATION OF GEOMETRIC AND STATIC STABILITY AND
CONTROL PARAMETERS FOR RADIO CONTROLLED SAILPLANE MODELS

By

James R. Stevens

INTRODUCTION

"AIRPSTAB" is a computer code for calculating the basic geometrical data and an estimate of the static stability and control derivatives for unpowered, low speed aircraft configurations. The program was developed for the design and analysis of radio controlled model sailplanes. The code is written in BASICA, and was developed using the following equipment: an IBM PC computer with 256K and two soft disc drives, a TAXAN RGB monitor, and an EPSON FX80 printer. Later revisions and modifications were done on an AST 286 AT Clone, and compiled using Quick Basic 3.

The program consists of two major sections. The first section inputs the basic dimensional data that are read from any reasonably accurate 3-view, and then calculates all of the dimensional data needed for the stability and control calculations. Primary dimensional results can be printed out and the input data can be displayed in the form of a schematic 3-view. The input dimensional data may be stored on the soft disc, and then retrieved and revised later if desired.

The second section of the code calculates the static stability and control derivatives using the calculated dimensional data and some additional aerodynamic input for the airfoil. The stability and control estimates are based on digital approximations of charts contained in the references and on other general aerodynamic junk collected over the years.

The results of the stability and control calculations have not been substantiated by comparison with wind tunnel or other data, and the absolute accuracy may or may not be very good. The program does, however, provide a consistent method for comparing configurations and has been used in the design of nine models so far, all of which flew very well. The code was first applied to a number of models that were already flying, and a data base was developed for existing models. A rough layout for a proposed design was then analyzed, and the areas and dimensions were adjusted by comparison with the data base. The handling qualities of the new model could then be predicted qualitatively by inference in comparison with the way existing models fly. The construction layout was then drawn using the final refined dimensions.

The program includes an airplane name file technique for storing and retrieving the input dimensional data on the disc. This part of the computer code was adapted, by permission, from Chuck Anderson's airfoil plotting code.

SUMMARY

This report contains a description of the methods, user instructions, an example application and results, and listings of the codes.

The first section describes the input required and the dimensional conventions. A sample input form is shown for a typical model. The resulting dimensional data print out and schematic three-view are included.

The second section gives a brief description of the methods used to obtain the static stability and control derivatives. A print out of these aerodynamic data for the example model is included.

The last part of the report describes the arrangement of the computer code, and a listing of the code in BASICA for an IBM PC computer.

A list of references is included.

DATA INPUT

The first order of business to run the program is to set the drive for the airplane dimensional data disk. You will be prompted for this after the opening messages. If the data disk is in the same drive as the program, just hit "ENTER". For any other drive, hit "D". This shells to DOS. Enter the data drive letter, "A :" or "B:", and then enter "EXIT". This will put you back in the program.

The calculation sequence is controlled by a menu with options A through M that appear on the screen at the start of AIRPSTAB and at the end of any one option. If the dimensional data have been stored on the disc previously, then Option B can be used to input the data. A menu type selection is provided for choosing from a list of configurations that may have been stored.

If a new configuration is to be input, Option A, "Configuration Definition", must be run before the dimensional data are entered with Option C. The items in the definition are self explanatory. The airplane name must conform to DOS file specification in that it can contain no more than eight letters and/or numbers and no spaces. The airfoil name is documentary and is printed on the output for information. To answer the questions, hit "Y" or "N" and hit RETURN. Option A also includes the option of printing a blank form for the input dimensional data.

The planforms of the wing and horizontal tail should be extended in to the center line along the leading and trailing edges, and the root dimensions are measured on the center line. The program provides for either one or two wing panels. An inner and outer panel should be defined in the following cases:

- (1) A planform break such as a constant chord inner panel and a tapered outer panel.

(2) A break in the dihedral angle such as polyhedral or a gull wing.

(3) An aileron.

A "Horizontal Tail Cut-out" means the vee shaped notch in the tail root trailing edge if it exists. In either case the tail root chord is defined as if the cut-out was not there.

All X-dimensions, except those noted, are measured from the nose, parallel to the center line, positive aft. All Y-dimensions are measured from the center line outboard, perpendicular to the center line. A Horizontal Reference Plane must be defined. If a Horizontal Reference Line is not shown on the 3-view it should be drawn in on the side and front view. This HRL can be aligned with any convenient horizontal reference on the side view, but in any case it must pass through a point midway between the top and bottom of the fuselage at the location of the wing root quarter-chord. If the wing rests on the top of the body, use the top of the wing as the top of the fuselage. In the front view, the HRL is a horizontal line at the same relative height as in the side view. All Z-dimensions are measured from the HRP, positive upward.

The units may be in any convenient system as long as they are consistent. A scale factor is requested by the code at the end of the input. This factor may be any desired value.

A complete set of dimensional data is entered using Option C. An example of the blank input form is shown in Figure. A walk-through of this form follows:

WING OR IN'R PANEL----- Inner wing panel, or entire wing if no
outer panel needed to be defined.
ROOT L.E.X -----X Dist. from nose to root l.e. on fuse.
C.L.
ROOT T.E.X -----X Dist. from nose to root t.e. on fuse
C.L.
TIP Y-STN -----Y Dist. from fuse. C.L. to panel tip.
TIP L.E.X & T.E.X -----X Dists for l.e. and t.e. of panel tip
Z @ CR/4 -----Vert. Dist. from HRL to wing ref line at
wing CR/4.
TIP Z. -----Vert. Dist from HRL to wing ref line at
panel tip.
THICK T/C ----- Wing panel average thickness ratio.

OUT'R PANEL OR AILERON- Outer wing panel as defined for planform
break, dihedral break, or aileron.
TIP Y-STN. -----Y Dist. from fuse C.L. to outer panel
tip.
TIP L.E.X & T.E.X -----X Dists for l.e. and t.e. of outer panel
tip.
TIP Z. -----Vert. Dist. from HRL to wing ref line at
outer tip.
AVE T/C ----- See inner panel.

If the aircraft has ailerons and they are called out in the configuration definition, the following dimensions will be requested.

AIL. R'T CHORD ----- Aileron root chord.
AIL. Y-TIP ----- Y Dist. from fuse C.L. to aileron tip.
AIL. TIP C. ----- Aileron tip chord.

HORIZ. TAIL

ROOT L.E.X ----- X Dist. from nose to root l.e. on C.L.
ROOT T.E.X ----- X Dist. from nose to root t.e. on C.L.
TIP Y-STN ----- Y Dist. from fuse. C.L. to H.T. tip
L.E.X & T.E.X ----- X Dist. from nose to tip l.e. and t.e.
H. H'T : HRL ----- Vert. dist from HRL to the H. Tail root.
If the horizontal has dihedral, use the vertical distance at about 1/3 the horizontal tail semi-span. If a Vee-Tail is called out in the configuration definition then the appropriate dimensions will be requested.
ELEVATOR ----- If there is an elevator it is assumed to extend the full span of the H. Tail. The elevator root and tip chords are input.
CUT-OUT ----- The cut-out span is the total width of the cut-out at the trailing edge. The cut-out chord is the distance on the center line between the extensions of the cut-out and the trailing edge.

VERTICAL TAIL

The root of the V. Tail is defined as a horizontal chord passing through the intersection of the V. Tail quarter-chord line and the top of the fuselage.

Z. R'T : HRL ----- The height of the root above the HRL.
ROOT L.E.X & T.E.X ----- X Dists. of root leading and trailing edges.
Z. T'P : HRL ----- The height of the tip above the HRL.
TIP L.E.X & T.E.X ----- X Dists. of tip leading and trailing edges.
THICK. T/C ----- Average thickness ratio of V. Tail.
RUDDER ----- The rudder dimensions are the total span and the root and tip chords.

BODY

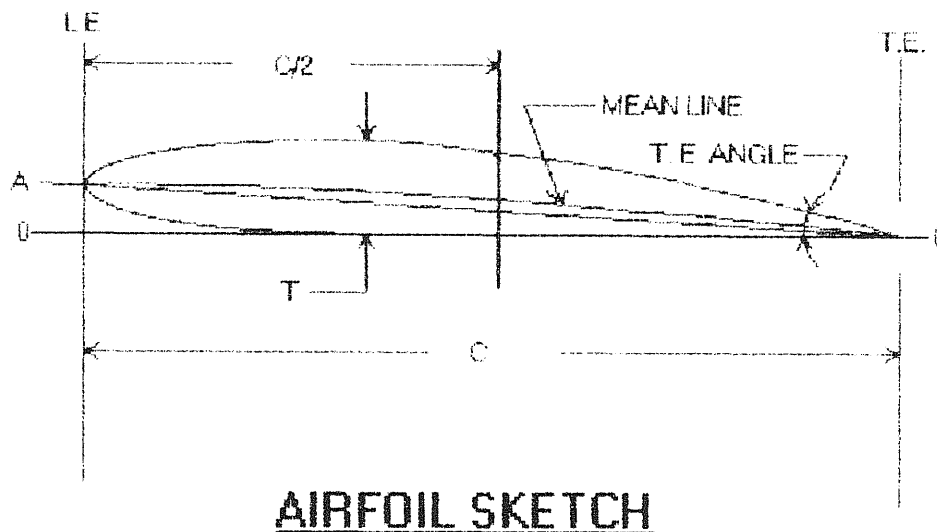
LENGTH ----- The total length of the body including the rudder "wrap-around" if any.
Z NOSE : HRL ----- The vertical distance from the extreme nose to the HRL.
Z TAIL : HRL ----- The vertical distance from a point midway between extensions of the body top and bottom and the HRL.
MAX H'T & W'TH ----- The max height and width of the body.
SQR OR OVAL ----- If the body is roughly square or rectangular: enter "S".
If it is nicely rounded: enter "O"

STN., HEIGHT, WIDTH --- The body height and width at the stations indicated. These dimensions are entered in the order shown; the computer code sorts them out.

ADDITIONAL FOR STAB AND CONTROL

Some of the additional data, required for the stability calculations, have been provided default values. To select the default value indicated just hit the return key.

- AIRFOIL ----- The name of the airfoil, if known. The airfoil data required below may be found in many published tables of airfoil data. More and more data are being published for airfoils appropriate for R/C sailplane models.
- RN. PER IN. ----- Reynold's Number per inch. The default is 20000 which is 200 000 for a ten inch chord.
- TRANSITION X/C ----- Chordwise location of transition from laminar to turbulent flow. The default value is .5.
- 1/2 T.E. SLOPE ----- 1/2 the trailing edge angle expressed as a positive slope. Refer to the sketch, Figure 2. The default for the H.T. is the T/C.
- INCIDENCE ----- The angle of incidence and the angle of zero lift must be consistent. The angle of incidence is the angle between a line parallel to the HRL and the wing root Airfoil Reference Line. The ARL may be either 0-0 or A-0 in the sketch below.



AIRF A0L ----- The angle of zero lift of the wing measured from the wing root ARL. The A0L is zero for a symmetrical and negative for a cambered airfoil. If the A0L is not known for the airfoil, the zero lift axis may be approximated by a line from the trailing edge through the mean line at C/2. Negative twist (washout) at the tip will reduce the wing A0L. Use a spanwise area weighted average.

AIRF CL/RAD ----- The airfoil two-dimensional lift curve slope per radian. The default is a calculated value using the airfoil thickness, t.e. slope, and the chord Reynold's Number.

AIRF CM0 ----- The airfoil quarter-chord pitching moment at zero lift. If this is not known for the airfoil it may be approximated as follows: Let ZC be the distance between the ARL A-0 and the Mean Line at C/2. Then $CM0 = -3*ZC/C$.

AIRF MIN CD ----- The minimum drag coefficient of the wing root airfoil. If not known, use $(T/C)/10$. The min. CD is used in the calculation of the dynamic pressure ratio at the tail.

The menu options D through J may be selected to change items or blocks of the input data without having to reenter the whole set for a given airplane. The input dimensions may be saved on the disc with option K.

INPUT DIMENSIONS FOR _____

WING OR IN'R PANEL

ROOT L.E.X _____
 ROOT T.E.X _____
 TIP Y-STN. _____
 TIP L.E.X _____
 TIP T.E.X _____
 Z. @ CR/4 _____
 TIP Z. : HRL _____
 THICK. T/C _____

OUT'R PANEL OR AIL.

TIP Y-STN. _____
 TIP L.E.X _____
 TIP T.E.X _____
 TIP Z. : HRL _____
 AVG T/C _____
 AIL. R'T CHD _____
 AIL. Y-TIP _____
 AIL. TIP C. _____

BODY

LENGTH _____
 Z NOSE : HRL _____
 Z TAIL : HRL _____
 MAX H'T. _____
 MAX W'TH. _____
 SQR OR OVAL _____

HORIZ. TAIL

ROOT L.E.X _____
 ROOT T.E.X _____
 TIP Y-STN _____
 TIP L.E.X _____
 TIP T.E.X _____
 H. H'T : HRL _____
 THICK. T/C _____
 ELE. R'T C. _____
 ELE. T'P C. _____
 CUT O'T SPAN _____
 CUT O'T CHD. _____

VERT. TAIL

Z.R'T. : HRL _____
 ROOT L.E.X _____
 ROOT T.E.X _____
 Z.T'P : HRL _____
 TIP L.E.X _____
 TIP T.E.X _____
 THICK. T/C _____
 RUD'R SPAN _____
 RUD'R R'T C. _____
 RUD'R TIP C. _____

STATION

NOSE _____
 1/4 TH LENGTH _____
 WING R'T L.E. _____
 WING R'T 1/4 CH'D _____
 WING R'T T.E. _____
 HALF LENGTH _____
 THREE-QUARTER LENGTH _____
 V. TAIL R'T 1/4 CHD _____
 BODY TAIL _____

HEIGHT

WIDTH

ADDITIONAL FOR STAB & CONT

RN PER IN. _____

AIRFOIL _____

TRANSITION X/C _____
 1/2 T.E. SLOPE _____
 INCIDENCE (DEG.) _____

WING _____

H. TAIL _____

AIRF AOL _____
 AIRF CL/RAD _____
 AIRF CMO _____
 AIRF MIN CD _____

FIGURE 1.

Option A of the main menu offers this printed form which can be filled in with the specific measurements of the aircraft to be analyzed. The blank form is a convenient item to take to the shop and fill in as you measure your design. All of the items on the list are defined in detail in the text above.

X BAR C/4 ----- X distance from nose to v. tail MAC/4.
V. TAIL LENGTH X dist. from wing MAC/4 to v. tail MAC/4.
SWEEP C/4 ----- Sweepback of the vertical tail quarter-chord.
L.V./BW ----- V. TAIL LENGTH / Wing SPAN.
SV/SW ----- V. tail area divided by wing area.
V.T. VOLUME --- The product L.V./BW times SV/SW.

Body:

MAX. HT. ----- Maximum height of the body.
MAX. WIDTH. ---- Maximum width of the body.
X-SECT.AREA --- Maximum frontal area of the body.
FINESS RATIO -- LENGTH divided by the diameter of a circle with
area equal to X-SECT. AREA.
PLAN AREA ----- Area of the plan view of the body.
PROF. AREA ----- Area of the side view of the body.
WET. AREA ----- Surface area of the body including that blanketed
by the wing and tail, and the canopy area.

At the end of the dimensional calculations a schematic 3-view of the configuration may be displayed. This is not intended to be a true 3-view of the airplane, but is meant to disclose any errors in the input. An example is shown in Figure 3.

AIRPLANE DIMENSIONS FOR PARAGON.

```

**** WING DIMENSIONS ****
SPAN          AREA          ASPECT RATIO    TAPER
118.000      1073.440          12.971          0.638

ROOT L.E. X   ROOT CHORD        TIP L.E. X     TIP CHORD
11.450       10.000           12.500         6.400

PANEL Y-STN.  PANEL L.E. X     PANEL CHORD
29.400       11.450           10.000

MAC          Y BAR          X BAR 0        X BAR C/4
9.246       27.551         11.670         13.981

WRP ABOVE FRL  IN DIHED.(DEG)  OUT DIHED.(DEG)'
0.900       4.599          11.449

**** HORIZONTAL TAIL DIMENSIONS ***
SPAN          AREA          ASPECT RAT.    TAPER
29.300      150.162          5.717          0.708

ROOT L.E. X   ROOT CHORD        TIP L.E. X     TIP CHORD
41.250       6.000           42.350         4.250

H. T. HT.    MAC H           X BAR C/4      H. TAIL LENGTH
0.900       5.175          43.062         29.081

SWEEP C/4    L.H./C BAR W    SH/SW          H.T. VOLUME
2.589       3.145           0.140          0.440

ELEVATOR CHORD RATIO    0.365

**** VERTICAL TAIL DIMENSIONS ****
SPAN          AREA          EFF. A.R.      TAPER
10.000       60.000          3.333          0.500

ROOT L.E. X   ROOT CHORD        TIP L.E. X     TIP CHORD
42.300       8.000           44.262         4.000

V. RT. HT.    MAC V           X BAR C/4      V. TAIL LENGTH
0.900       6.222          44.728         30.746

SWEEP C/4    L.V./BW         SV/SW          V.T. VOL
5.4950      0.2606          0.0559         0.0146

RUDDER CHORD RATIO    0.579

**** BODY DIMENSIONS ****
LENGTH       MAX. HT.         MAX. WPTH.     FINESS RATIO
50.500      4.400            2.800          12.751

X-SECT. AREA  PLAN AREA        PROF. AREA      WET. AREA
12.320      92.259          153.501        491.520

```

FIGURE 2.

A printout of the aircraft geometry is offered as an option of the main menu. This example is from the pre-entered configuration of the PARAGON.

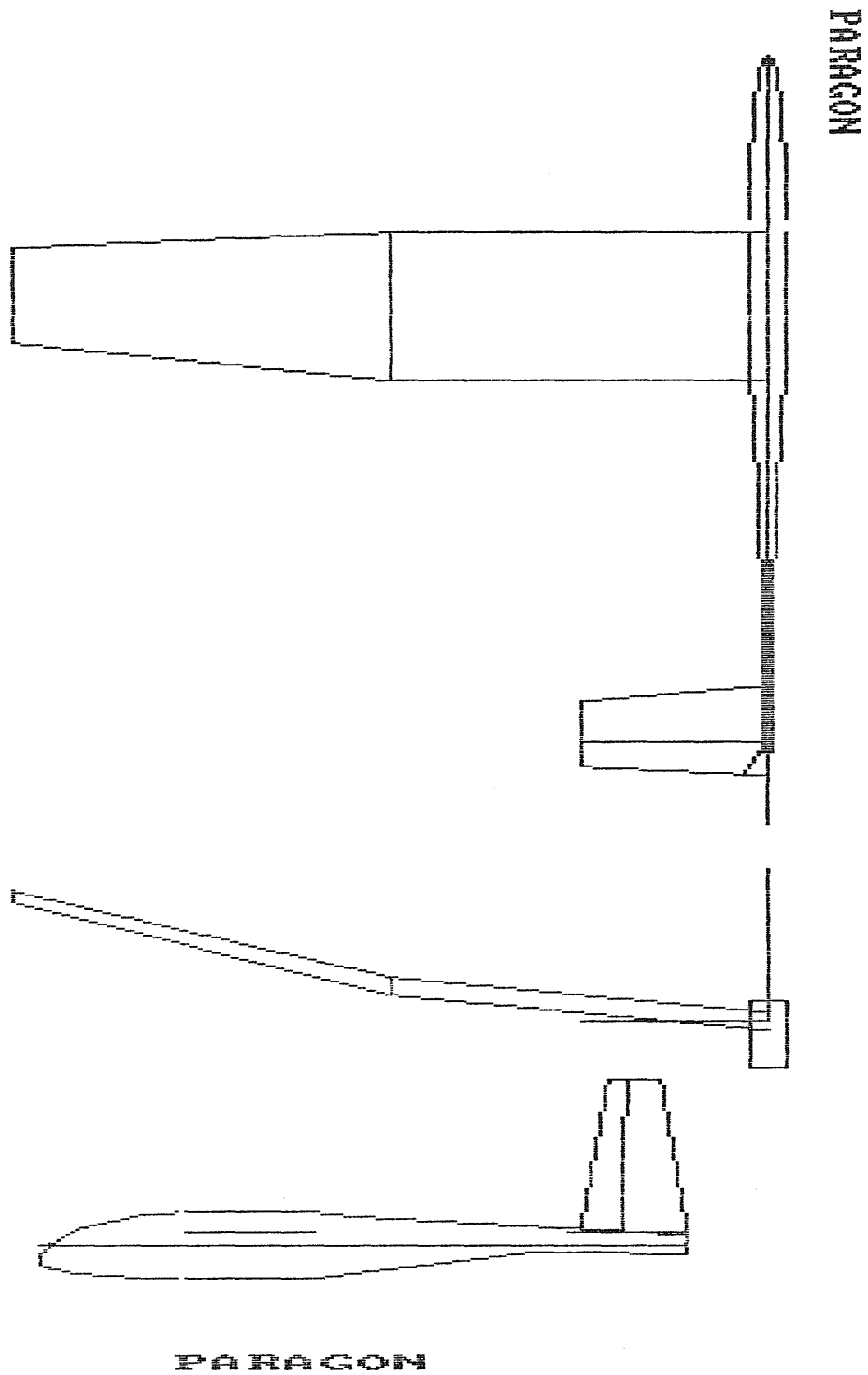


FIGURE 3.

The program provides an on-screen sketch of the design which represents an approximate set of outlines for the model that has been entered.

STABILITY AND CONTROL CALCULATIONS

The stability and control calculations consist of estimates of the static longitudinal, lateral, and directional derivatives. The methods are based on material contained in the References, and have been tailored, where appropriate, to relatively high aspect ratio, unswept wings and lower Reynold's Numbers. In some cases, empirical equations have already been derived. In other cases the method selected consisted of charts. These charts were "curve-fitted" to produce formulas for the computer code. The geometry parameters in the charts were generally limited to conventional configurations, and the fitting equations were developed such that logical extrapolations to sailplane-like configurations would result. This procedure can be dangerous, but so far, for a large number of cases, the results have not shown anything unexpected.

I am not going to present a big mess of equations. The line index, below, gives the location of the various functional calculations in the computer code.

The geometry calculations, Option L, must be run before the stability and control calculations, Option M. During the calculations, a center of gravity location, as a fraction of the wing MAC, will be requested. Up to nine c.g.'s may be input, but I usually use .25, .30, and .35. Input "NP" for the c.g. at the neutral point, and input "E" to get out of this loop.

Figure 4 is a print out of the results for the example PARAGON. After the heading, the following data are listed:

ALO x -----Angles of attack of the HRL for zero lift of the
 Body, Wing, Wing-Body, and Wing-Body-Horiz.
CLA x -----Slopes of the lift curves per degree angle of
 attack for the Wing, Horizontal Tail and Wing-
 Body-Horiz.
CLA V ----- Side force slope per degree sideslip for the
 Vert.tail.
CM0 x ----- Pitching moment at zero lift for the components
 x.
A.C. W ----- Aerodynamic center (zero change in pitching
 moment with angle of attack) for the wing in
 fraction of the MAC.
D A.C. WB ----- Shift in aerodynamic center due to the body.
A.C. WB ----- Aerodynamic center of the wing-body combination.
NEUT. PT. ----- Neutral Point. The fraction of wing MAC for zero
 change in pitching moment with angle of attack for
 the combination.
EPS 0A ----- Average downwash across the Horiz. Tail at zero
 angle of attack.
DEPS/DA ----- Slope of downwash per degree angle of attack.
QH/Q ----- Ratio of dynamic pressure at the Horiz. Tail to
 the free stream dynamic pressure. At zero angle of
 attack.
DCL/DE ----- Change in airplane lift coefficient per degree
 deflection of the H. Tail or Elevator.
DCM/DE ----- Change in airplane pitching moment coefficient

per degree deflection of the H. Tail or Elevator.
DEO TRIM ----- Angle of deflection for the H.T. or Elev. for
trim at zero lift of the airplane.
DEO=CMOWBH/DCMDE.

Stability And Control vs. C.G.:

For the c.g. locations input and listed:

CM/CL WB ----- Slope of the pitching moment vs. lift coefficient
with the horizontal tail off.
CM/CL WBH ----- Slope of the pitching moment vs. lift coefficient
with the horizontal tail on.
DE/DCL TRIM --- Slope of H.T. or Elev. deflection in deg. vs.
lift coefficient to trim.

Lateral and Directional Derivatives:

CLLB x ----- Rolling moment coefficient due to sideslip.
Negative is stable.
DIHED - Due to dihedral
BODY -- Increment due to the body.
W.HT.-- Increment due to the wing vertical location on the
body.
V.T. -- Increment due to the vertical tail.
AIRP.-- The total for the Airplane.

CLNB x ----- Yawing moment coefficient due to sideslip.
Positive is stable.
V.T. -- Due to vertical tail.
WB ---- Increment due to Wing-Body.
AIRP. - Total for the Airplane.

EFF. DIHED. --- Effective wing dihedral in degrees.
CLLB/CL ----- Slope of rolling moment due to sideslip vs. lift
coefficient.
CLL/AIL. ----- Rolling moment coefficient due to aileron
deflection, per radian.
CLN/RUD. ----- Yawing moment coefficient due to rudder
deflection, per radian.

STABILITY AND CONTROL FOR PARAGON.

WITH AIRFOIL CY-12

*** LONGITUDINAL DERIVATIVES ARE PER DEG.

ALO B	1.47462	CLA W	0.09158
ALO W	-4.21200	CLA H	0.07250
ALO WB	-3.76349	CLA V	0.06209
ALO WBH	-3.50948	CLA WBH	0.09663
CMO W	-0.05744	A.C. W	0.24733
CMO B	-0.00168	D A.C. WB	0.00756
CMO WB	-0.05912	A.C. WB	0.23978
CMO WBH	0.06732	NEUT. PT.	0.40478
EPS 0A	2.31188	DCL/DE	0.00778
DEPS/DA	0.49782	DCM/DE	-0.02327
QH/Q	0.99208	DE0 TRIM	2.89239

*** STABILITY AND CONTROL VS. C.G.

C.G.	CM/CL WB	CM/CL WBH	DE/DCL TRIM
0.40478	0.16501	0.00000	0.00000

*** LATERAL AND DIRECTIONAL DERIVATIVES ARE PER RADIAN

CLLB DIHED	-0.14851	EFF. DIHED.	9.21809
CLLB BODY	-0.00010		
CLLB W. HT.	-0.00514	CLLB/CL	0.03839
CLLB V.T.	-0.00593		
CLLB AIRP.	-0.15968	CLL/AIL.	0.00000
CLNB V.T.	0.06150	CLN/RUD.	-0.05817
CLNB WB	-0.00323		
CLNB AIRP.	0.05827		

FIGURE 4.

The final output of the program is the results of the stability calculations for the aircraft that has been entered. In this listing the aircraft is the PARAGON where CG location has been specified at the Neutral Point.

COMPUTER CODE

A listing of the computer code is provided. The code is organized into control codes and subroutines. Individual operations within the main blocks are indicated by REM comments. REM comments are used liberally to indicate what is going on. The blocks of line numbers for main operations and a line index, which provides a list of the items considered, follows:

Lines 0 to 1000 ----- Calculation control and input control and storage menus.

Lines 1000 to 4000 ---- Control the input of; changes to; and storage and print out of the geometry data.

Lines 4000 to 6000 ---- Subroutines for Airplane data storage name file.

Lines 6000 to 10000 --- Sub. to display the input configuration.

Lines 10000 to 20000 -- Subs to input geom. data.

10010 ----- Wing or inner panel dims

10200 ----- Outer panel dims.

10320 ----- Aileron dims.

10400 ----- Horizontal tail dims.

10650 ----- Vertical tail dims.

10890 ----- Body dimensions.

11160 ----- Stability and control data.

12000 ----- Sub to rescale input dims.

Lines 20000 to 30000 -- Subs for geometry calculations.

20000 ----- Wing or inner panel.

20230 ----- Outer panel and/or aileron

20500 ----- Horizontal tail.

20730 ----- Vertical tail.

20980 ----- Sorts body wdth and ht stations.

21150 ----- Body
22000 ----- Vee tail.

Lines 30000 to 40000 -- Subs for stability and control calcs.

30010 ----- Conv. AL0 to rads.
30040 ----- 2-dim. lift curve slope.
30180 ----- Panel lift curve slope.
30380 ----- Effect of H. tail cut-out.
30460 ----- Wing aero. center.
30550 ----- Wing-body A.C. incr.
30670 ----- AL0 and downwash.
31010 ----- Dyn. Press. ratio at tail.
31220 ----- Body CM0.
31310 ----- Wing - body CM0.
31330 ----- Roll due to dihedral.
31550 ----- Roll vs. lift coeff.
31610 ----- Roll due to body and wing ht.
31800 ----- Roll and yaw for vert. tail.
32130 ----- Sum roll due to sideslip.
32150 ----- Body yawing moment.
32290 ----- Sum yaw due to sideslip.
32310 ----- Elev. and Rud. effect.
32520 ----- Aileron 2-dim. eff.
32650 ----- Aileron panel eff.
32770 ----- Neut. pt., C.G. and CM/CL.
33200 ----- Print stab. and cont.
35000 ----- Added sub for roll and yaw for Vee-tail.

Lines 40000 to end ---- Sub for dimensional data print.

CONCLUSIONS

A computer program has been developed which calculates the basic dimensional data for R/C sailplane model configurations from dimensions obtained from a three-view. The computer code then calculates an estimate of the static longitudinal and lateral and directional stability and control derivatives. No attempt is made to evaluate the accuracy of the results. I suggest you do what I did and run a number of models with which you are familiar. You will then have a collection of data for models with known flying qualities for comparison with future models.

I want to stress, again, that static stability is only part of the answer. A radio controlled model is a dynamic system. The flying qualities will also depend equally on other factors such as the control mode and the aerodynamic damping and moments of inertia in the three axes. One could probably completely change the flying qualities of someone's Paragon, for example, by burying a couple of large fish-sinkers in each wing tip.

The objective was to develop a tool for use in sailplane model design and aerodynamics, and I hope that those of you who are interested in this type of analytical activity will find the program useful and/or educational. I would certainly welcome any and all suggestions and criticisms.

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```

1 PRINT " AIRPSTB8 MOD. AIRPLANE DIMENSIONS AND STABILITY AND CONTROL"
2 PRINT " COPYRIGHT J. R. STEVENS, SAN PEDRO CA, 1986"
3 PRINT " CONFIGURATION DISPLAY ADDED 11-86, INPUT DATA FORMS 8/88"
4 PRINT " INCLUDES VEE-TAIL YAW AND ROLL, 9-86. COMPILED AS AIRPSTAB"
5 PRINT " MOD FOR DIRECTORY FILES INPUT FOR DISC. APRIL 1990"
6 PRINT " STORED AS AIRPSTB8.BAS. COMPILED FROM AIRPSTAB.BAS"
7 PRINT
8 PRINT " HIT ANY KEY TO START"
9 START$=INKEY$:IF START$="" THEN 9
10 CLS:PRINT
11 PRINT " TO CHANGE DEFINITION OF AN EXISTING CONFIGURATION, FIRST LOAD"
12 PRINT " THE DIM. DATA USING OPTION B THEN RUN OPTION J. STORE THE REVISED"
13 PRINT " DATA UNDER A NEW NAME."
20 PRINT
30 PRINT " DEFINE FUSELAGE REFERENCE LINE TO PASS THROUGH THE MID-HEIGHT"
40 PRINT " OF THE BODY AT THE WING ROOT QUARTER-CHORD"
45 PRINT
50 PRINT " THE VERT. TAIL ROOT IS TAKEN AT THE INTERSECT. OF THE VERT."
55 PRINT " 1/4 CHORD AND THE BODY UPPER M.L."
60 PRINT
65 PRINT " HIT ANY KEY TO CONTINUE"
70 CONT$=INKEY$:IF CONT$="" THEN 70
75 PI=3.14159265#
80 DIM X(8),H(8),W(8),BPRM(8)
85 DIM CG(10),CMCLWB(10),CMCLWBH(10),DEDCL(10)
90 DIM N$(250),PLANE$(250)
95 GOSUB 5800 'SET DATA DRIVE
100 CLS:PRINT " SELECT LETTER FOR DESIRED OPERATION"
110 PRINT
120 PRINT " CONFIGURATION DEFINITION.
121 PRINT " MUST RUN FIRST FOR NEW CONFIG."
125 PRINT " OR LOAD DATA FROM DISK AND CHANGE IF DESIRED _____ A"
130 PRINT " LOAD DIMENSIONAL INPUT FROM DISK _____ B"
140 PRINT " INPUT ALL BASIC DIMENSIONS _____ C"
150 PRINT " CHANGE WING OR INNER PANEL DIMENSIONS _____ D"
160 PRINT " CHANGE OUTER PANEL OR AILERON DIMS. _____ E"
170 PRINT " CHANGE HORIZONTAL TAIL DIMS. _____ F"
180 PRINT " CHANGE VERTICAL TAIL DIMS. _____ G"
190 PRINT " CHANGE BODY DIMENSIONS _____ H"
200 PRINT " CHANGE STABILITY AND CONTROL DATA ,AND NAMES _____ J"
210 PRINT " SAVE DIMENSIONAL BASIC DATA ON DISK _____ K"
220 PRINT " CALCULATE AND PRINT CONFIG. DIMENSIONS "
221 PRINT " ALWAYS RUN BEFORE STABILITY AND CONTROL _____ L"
230 PRINT " CALC. AND PRINT STABILITY AND CONTROL DATA _____ M"
240 PRINT " CHANGE DATA DRIVE AND PATH _____ N"
290 PRINT
300 D$=INKEY$: IF D$="" THEN 300
310 IF D$="A" THEN 600
320 IF D$="B" THEN 800
330 IF D$="C" THEN 1000
340 IF D$="D" THEN 1500
350 IF D$="E" THEN 1800
360 IF D$="F" THEN 2100
370 IF D$="G" THEN 2400
380 IF D$="H" THEN 2700
390 IF D$="J" THEN 2900
400 IF D$="K" THEN 3300

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410 IF D$="L" THEN 3500
420 IF D$="M" THEN 3700
425 IF D$="N" THEN GOSUB 5800
430 GOTO 100
600 'CONFIGURATION DEFINITION -----
601 PRINT "      PRINT INPUT DATA BLANK FORM Y/N ?"
602 PTFM$=INKEY$:IF PTFM$="" THEN 602
603 IF PTFM$<>"Y" THEN 606
604 GOSUB 9000
605 GOTO 100
606 PRINT
610 INPUT " CONFIGURATION NAME _____ " ,AIRP$
620 INPUT " IS THERE AN OUTER WING PANEL Y/N ? _____ " ,TP$
630 INPUT " IS THERE AN AILERON Y/N ? _____ " ,AL$
640 INPUT " IS THERE A HORIZONTAL TAIL Y/N ? _____ " ,HT$
645 IF HT$<>"Y" THEN 670
646 INPUT " IS IT A VEE-TAIL Y/N ? _____ " ,VTL$
650 INPUT " TYPE `AM` FOR ALL MOVE. `EL` FOR ELEVATOR _____ " ,HC$
660 INPUT " IS THERE A HORIZ. TAIL T.E. CUT-OUT Y/N ? _____ " ,CO$
670 INPUT " BODY X-SECT, TYPE `O` FOR OVAL, `S` FOR SQUARE _____ " ,BX$
680 INPUT " AIRFOIL NAME _____ " ,AF$
700 PRINT
710 GOTO 100 '*****
800 'LOAD DIM. DATA FROM FILE *****
805 GOSUB 5000:GOSUB 5100:GOSUB 5500 'PLANE NAME FILE DISPLAY AND SELECTION
810 IF N$="E" OR N$="e" THEN N$="E": GOTO 100 '-----
815 OPEN "I",#2,AIRP$
820 INPUT #2,TP$,AL$,HT$,HC$,CO$,BX$,AF$
825 INPUT #2,X1W,X2W,Y1W,X3W,X4W,ZW,ZW2,TCW1,Y2W,X5W,X6W,ZW3,TCW2,ALCR,YATP
830 INPUT #2,ALCT,X1H,X2H,Y1H,X3H,X4H,ZH,TCH,CE1,CE2,BCO,COO,Z1V,X1V,X2V
840 INPUT #2,Z2V,X3V,X4V,TCV,BR,CRRT,CRTP,LB,ZBN,ZBB,HB,WB,H25L,W25L,H1W
850 INPUT #2,W1W,HRTW4,WRTW4,H2W,W2W,H5L,W5L,H75L,W75L,HRTV4,WRTV4,HL,WL
860 INPUT #2,RNIN,XTRW,XTRH,TEPSW,TEPSH,IWD,IHD,ALOWA,AOTW,CMOA,CDOW
870 CLOSE #2
880 IF HT$="V" THEN VTL$="Y" ELSE VTL$="N"
890 IF HT$="V" THEN HT$="Y"
900 GOSUB 12000 'RESCALE DIMS
910 PRINT
920 PRINT "      PRINT INPUT DIMENSIONS TABLE, Y/N ?"
930 INDM$=INKEY$:IF INDM$="" THEN 930
940 IF INDM$<>"Y" THEN 960
950 GOSUB 14000
960 GOTO 100 '-----
1000 'INPUT ALL BASIC DATA -----
1010 FOR NUM=1 TO 8 'WING OR INNER PANEL
1020   ON NUM GOSUB 10010,10050,10070,10090,10110,10130,10150,10170
1030 NEXT NUM
1040 IF TP$<>"Y" AND AL$<>"Y" THEN 1114
1050 FOR NUM=1 TO 5 'OUTER PANEL
1060   ON NUM GOSUB 10200,10240,10260,10280,10300
1070 NEXT NUM
1080 IF AL$<>"Y" THEN 1114
1090 FOR NUM=1 TO 3 'AILERON
1100   ON NUM GOSUB 10330,10350,10370
1110 NEXT NUM
1114 IF VTL$<>"Y" THEN 1118
1115 PRINT " ENTER VEE-TAIL DIMS. AS HORIZ. TAIL FROM PLAN VIEW"
1116 PRINT "HEIGHT FROM FRL = HT. OF V-TAIL AT CENT. LINE (FROM FRL)"

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1117 PRINT
1118 IF HT$<>"Y" THEN 1230
1120 FOR NUM=1 TO 7 'HORIZONTAL TAIL
1130   ON NUM GOSUB 10400,10440,10460,10480,10500,10520,10540
1140 NEXT NUM
1150 IF HCS="AM" THEN 1190
1160 FOR NUM=1 TO 2 'ELEVATOR
1170   ON NUM GOSUB 10560,10580
1180 NEXT NUM
1190 IF COS<>"Y" THEN 1221
1200 FOR NUM=1 TO 2 'TAIL T.E. CUT-OUT
1210   ON NUM GOSUB 10600,10620
1220 NEXT NUM
1221 IF VTL$<>"Y" THEN 1230
1222 PRINT
1223 PRINT "  ENTER V-TAIL TIP HEIGHT FROM ROOT OF V-TAIL AT CENT. LINE"
1224 PRINT
1225 GOSUB 10740
1226 PRINT
1227 GOTO 1300
1230 FOR NUM=1 TO 10 'VERTICAL TAIL
1240   IF NUM>8 THEN 1270
1250   ON NUM GOSUB 10650,10700,10720,10740,10760,10780,10800,10820
1260   GOTO 1290
1270   NUM2=NUM-8
1280   ON NUM2 GOSUB 10840,10860
1290 NEXT NUM
1300 FOR NUM=1 TO 6 'BODY DIMENSIONS
1310   ON NUM GOSUB 10890,10930,10950,10970,10990,11010
1320 NEXT NUM
1330 FOR NUM=1 TO 11 'STAB. AND CONT DATA
1340   IF NUM>8 THEN 1370
1350   ON NUM GOSUB 11150,11230,11260,11290,11310,11340,11360,11380
1360   GOTO 1390
1370   NUM2=NUM-8
1380   ON NUM2 GOSUB 11400,11420,11440
1390 NEXT NUM
1395 GOSUB 12000 'RESCALE
1400 GOTO 100 '-----
1500 'CHANGE WING OR INNER PANEL DIMS -----
1510 PRINT
1520 PRINT "  ENTER NUMBER FOR DESIRED ITEM TO CHANGE"
1530 PRINT
1540 PRINT "      NUMBER      ITEM                                CURRENT VALUE"
1550 PRINT
1560 PRINT USING "      1      ROOT L.E. X-STN                                ###.#####";X1W
1570 PRINT USING "      2      ROOT T.E. X-STN                                ###.#####";X2W
1580 PRINT USING "      3      TIP Y-STN                                  ###.#####";Y1W
1590 PRINT USING "      4      TIP L.E. X-STN                                ###.#####";X3W
1600 PRINT USING "      5      TIP T.E. X-STN                                ###.#####";X4W
1610 PRINT USING "      6      HT. OF WRP ABOVE FRL AT WING C-ROOT/4        ###.#####";ZW
1620 PRINT USING "      7      WING OR INNER PANEL TIP HT. ABOVE FRL          ###.#####";ZW2
1630 PRINT USING "      8      WING OR INNER PANEL THICKNESS RATIO          ###.#####";TCW1
1640 PRINT
1650 INPUT "  ENTER NUMBER (9 FOR OUT) ",NUM
1660 IF NUM=9 THEN 100
1670 ON NUM GOSUB 10030,10050,10070,10090,10110,10130,10150,10170
1680 PRINT

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```

1690 GOTO 1510 '-----
1800 ' CHANGE OUTER PANEL DIMS -----
1810 PRINT
1820 PRINT " ENTER NUMBER FOR DESIRED ITEM TO CHANGE"
1830 PRINT
1840 PRINT "      NUMBER      ITEM                                CURRENT VALUE"
1850 PRINT
1860 PRINT USING "      1      TIP Y-STN                                ###.#####;Y2W
1870 PRINT USING "      2      TIP L.E. X-STN                            ###.#####;X5W
1880 PRINT USING "      3      TIP T.E. X-STN                            ###.#####;X6W
1890 PRINT USING "      4      OUTER TIP HT. ABOVE FRL                    ###.#####;ZW3
1900 PRINT USING "      5      OUTER PANEL AVG. THICK. RATIO            ###.#####;TCW2
1910 PRINT USING "      6      AILERON ROOT CHORD                        ###.#####;ALCR
1920 PRINT USING "      7      AILERON TIP Y-STN.                        ###.#####;YATP
1930 PRINT USING "      8      AILERON TIP CHORD                          ###.#####;ALCT
1940 PRINT
1950 INPUT " ENTER NUMBER (9 TO OUT) ",NUM
1960 IF NUM=9 THEN 100
1970 ON NUM GOSUB 10220,10240,10260,10280,10300,10330,10350,10370
1980 GOTO 1810 '-----
2100 'CHANGE HORIZONTAL TAIL DIMENSIONS -----
2110 PRINT
2120 PRINT " ENTER NUMBER FOR DESIRED ITEM TO CHANGE"
2130 PRINT
2140 PRINT "      NUMBER      ITEM                                CURRENT VALUE"
2150 PRINT
2160 PRINT USING "      1      ROOT L.E. X-STN                                ###.#####;X1H
2170 PRINT USING "      2      ROOT T.E. X-STN                            ###.#####;X2H
2180 PRINT USING "      3      TIP Y-STN                                ###.#####;Y1H
2190 PRINT USING "      4      TIP L.E. X-STN                            ###.#####;X3H
2200 PRINT USING "      5      TIP T.E. X-STN                            ###.#####;X4H
2210 PRINT USING "      6      HEIGHT FROM FRL                            ###.#####;ZH
2220 PRINT USING "      7      HORIZ. TAIL THICKNESS RATIO                ###.#####;TCH
2230 PRINT USING "      8      ELEVATOR ROOT CHORD AT CENT. LINE          ###.#####;CE1
2240 PRINT USING "      9      ELEVATOR TIP CHORD                            ###.#####;CE2
2250 PRINT USING "     10      H. TAIL CUT-OUT SPAN AT T.E.              ###.#####;BCO
2260 PRINT USING "     11      H. TAIL CUT-OUT CHORD AT CENT. LINE      ###.#####;CCO
2270 PRINT
2280 INPUT " ENTER NUMBER (12 TO OUT) ",NUM
2290 IF NUM=12 THEN 100
2300 IF NUM>8 THEN 2330
2310 ON NUM GOSUB 10420,10440,10460,10480,10500,10520,10540,10560
2320 GOTO 2110
2330 NUM2=NUM-8
2340 ON NUM2 GOSUB 10580,10600,10620
2350 GOTO 2110 '-----
2400 'CHANGE VERTICAL TAIL DIMENSIONS -----
2410 PRINT
2420 PRINT " ENTER NUMBER FOR DESIRED ITEM TO CHANGE"
2430 PRINT
2440 PRINT "      NUMBER      ITEM                                CURRENT VALUE"
2450 PRINT
2460 PRINT USING "      1      HEIGHT OF VERT. ROOT ABOVE FRL                        ###.#####;Z1V
2470 PRINT USING "      2      ROOT L.E. X-STN                            ###.#####;X1V
2480 PRINT USING "      3      ROOT T.E. X-STN                            ###.#####;X2V
2490 PRINT USING "      4      HT. OF VERT. TIP ABOVE FRL                    ###.#####;Z2V
2500 PRINT USING "      5      TIP L.E. X-STN                            ###.#####;X3V
2510 PRINT USING "      6      TIP T.E. X-STN                            ###.#####;X4V

```

```

2520 PRINT USING "      7          VERT. TAIL THICKNESS RATIO          ###.#####";TCV
2530 PRINT USING "      8          RUDDER SPAN                        ###.#####";BR
2540 PRINT USING "      9          RUDDER ROOT CHORD                 ###.#####";CRRT
2550 PRINT USING "     10          RUDDER TIP CHORD                   ###.#####";CRTP
2560 PRINT
2570 INPUT " ENTER NUMBER (11 TO OUT) ",NUM
2580 IF NUM=11 THEN 100
2590 IF NUM>8 THEN 2620
2600 ON NUM GOSUB 10680,10700,10720,10740,10760,10780,10800,10820
2610 GOTO 2410
2620 NUM2=NUM-8
2630 ON NUM2 GOSUB 10840,10860
2640 GOTO 2410 '-----
2700 'CHANGE BODY DIMENSIONS -----
2710 PRINT
2720 PRINT " ENTER NUMBER FOR DESIRED ITEM TO CHANGE"
2730 PRINT
2740 PRINT "      NUMBER      ITEM                                CURRENT VALUE"
2750 PRINT
2760 PRINT USING "      1          BODY LENGTH                        ###.#####";LB
2770 PRINT USING "      2          VERT. DIST. FROM FRL TO BODY NOSE  ###.#####";ZBN
2780 PRINT USING "      3          VERT. DIST. FROM FRL TO BODY TAIL  ###.#####";ZBB
2790 PRINT USING "      4          MAX. BODY HIEGHT                    ###.#####";HB
2800 PRINT USING "      5          MAX. BODY WIDTH                      ###.#####";WB
2810 PRINT "      6          BODY HT. AND WDTH. VS L. DATA (TABLE)"
2820 PRINT
2830 INPUT " ENTER NUMBER (7 TO OUT) ",NUM
2840 IF NUM=7 THEN 100
2850 ON NUM GOSUB 10910,10930,10950,10970,10990,11010
2860 GOTO 2710 '-----
2900 'CHANGE STAB. AND CONT. DATA -----
2910 PRINT
2920 PRINT " ENTER NUMBER FOR DESIRED ITEM TO CHANGE"
2930 PRINT
2940 PRINT "      NUMBER      ITEM                                CURRENT VALUE"
2950 PRINT
2960 PRINT USING "      1          REYNOLD`S NUMBER PER INCH                    #####.#####";RNIN
2970 PRINT USING "      2          TRANS. PT. ON WING                          ###.#####";XTRW
2980 PRINT USING "      3          TRANS. PT. ON H. TAIL                       ###.#####";XTRH
2990 PRINT USING "      4          WING AIRF. 1/2 T.E. ANGLE                    ###.#####";TEPSW
3000 PRINT USING "      5          H. TAIL AIRF 1/2 T.E. ANGLE                 ###.#####";TEPSH
3010 PRINT USING "      6          WING INCIDENCE                                ###.#####";IWD
3020 PRINT USING "      7          H. TAIL INCIDENCE                            ###.#####";IHD
3030 PRINT USING "      8          WING ANGLE OF ZERO LIFT                        ###.#####";ALOWA
3040 PRINT USING "      9          AIRF. LIFT CURVE SLOPE                       ###.#####";AOTW
3050 PRINT USING "     10          ZERO-LIFT PITCHING MOMENT                 ###.#####";CMOA
3060 PRINT USING "     11          ROOT AIRF. ZERO-LIFT DRAG COEFF.         ###.#####";CDOW
3065 PRINT "     12          AIRFOIL NAME                                ";AF$
3070 PRINT "     13          CONFIG. NAME                                  ";AIRP$
3075 PRINT
3080 INPUT " ENTER NUMBER (14 TO OUT) ",NUM
3085 IF NUM=14 THEN 100 '*****
3090 IF NUM=12 THEN 680
3094 IF NUM<>13 THEN 3100
3096 INPUT " CONFIGURATION NAME _____ ",AIRP$
3100 IF NUM>8 THEN 3140
3120 ON NUM GOSUB 11200,11230,11260,11290,11310,11340,11360,11380
3130 GOTO 2910

```

```

3140 NUM2=NUM-8
3150 ON NUM2 GOSUB 11400,11420,11440
3160 GOTO 2910 '-----
3300 'SAVE DIM. DATA ON FILE -----
3310 PRINT
3311 PRINT " IS CONFIGURATION NAME FOR FILING ",AIRP$, " Y/N ?"
3312 PRINT
3313 NFF$=INKEY$:IF NFF$="" THEN 3313
3314 IF NFF$="Y" THEN 3337
3320 INPUT " CONFIGURATION NAME FOR FILING " ,AIRP$
3330 PRINT
3337 IF VTL$="Y" THEN HT$="V"
3340 OPEN "O",#1,AIRP$
3345 WRITE #1,TP$,AL$,HT$,HC$,CO$,BXS$,AF$
3350 WRITE #1,X1W,X2W,Y1W,X3W,X4W,ZW,ZW2,TCW1,Y2W,X5W,X6W,ZW3,TCW2,ALCR,YATP
3360 WRITE #1,ALCT,X1H,X2H,Y1H,X3H,X4H,ZH,TCH,CE1,CE2,BCO,CCO,Z1V,X1V,X2V
3370 WRITE #1,Z2V,X3V,X4V,TCV,BR,CRRT,CRTP,LB,ZBN,ZBB,HB,WB,H25L,W25L,H1W
3380 WRITE #1,W1W,HRTW4,WRTW4,H2W,W2W,H5L,W5L,H75L,W75L,HRTV4,WRTV4,HL,WL
3390 WRITE #1,RNIN,XTRW,XTRH,TEPSW,TEPSH,IWD,IHD,ALOWA,AOTW,CMOA,CDOW
3400 CLOSE
3410 GOTO 100 '-----
3500 'CALC AND PRINT CONFIGURATION DIMENSIONS -----
3510 GOSUB 20000 'WING OR INNER PANEL
3520 IF TP$<>"Y" AND AL$<>"Y" THEN 3540
3530 GOSUB 20230 'OUTER PANEL AND AILERON
3540 IF HT$<>"Y" THEN 3560
3545 IF VTL$="Y" THEN GOSUB 22000 ELSE 3550 'V-TAIL DIMENSIONS
3546 GOTO 3570
3550 GOSUB 20500 'H. TAIL
3560 IF Z2V=0 THEN 3570
3561 GOSUB 20730 'V. TAIL
3570 IF LB=0 THEN 3581
3571 GOSUB 20980 'SORT OUT BODY DIMS
3580 GOSUB 21150 'BODY DIMS
3581 PRINT
3582 PRINT " PRINT DIMENSIONAL DATA Y/N ?"
3583 PDIM$=INKEY$:IF PDIM$="" THEN 3583
3584 IF PDIM$<>"Y" THEN 3650
3590 GOSUB 40000 'PRINT AIRP AND WING
3600 IF HT$<>"Y" THEN 3620
3610 GOSUB 40210 'PRINT H. TAIL
3620 GOSUB 40370 'PRINT V. TAIL
3630 GOSUB 40530 'PRINT BODY
3650 PRINT " DISPLAY INPUT CONFIGURATION Y/N ?"
3660 DSP$=INKEY$:IF DSP$="" THEN 3660
3670 IF DSP$<>"Y" THEN 3690
3680 GOSUB 6000
3690 GOTO 100
3700 'STABILITY AND CONTROL CALCULATIONS AND PRINT -----
3710 GOSUB 30000
3711 IF VTL$<>"Y" THEN 3720
3712 Y1H=Y1H/COS(GAMVT) 'RESETS Y1H TO PLANFORM VALUE
3720 GOTO 100 '-----
3800 'END -----
5000 ' SUB TO SELECT DATA FILES *****
5010 PRINT:PRINT:PRINT " PUT DATA DISK IN DATA DRIVE THEN HIT ANY KEY"
5020 AA$=INKEY$: IF AA$="" GOTO 5020
5030 RETURN '*****

```

```

5100 'GENERATE AIRPLANE NAMES FILE *****
5110 CLS: PRINT: PRINT: PRINT "GENERATING AIRPLANE NAME FILE.": PRINT
5120 'Makes sure FILE.DAT is up to date
5130 SHELL "DIR /O-D > FILE.DAT"
5140 NUMFILES = 114
5150 OPEN "FILE.DAT" FOR INPUT AS #1
5160 FOR I=1 TO 4: REM Dump overhead records
5170     LINE INPUT #1,TEXT$
5175     PRINT "DUMPING THE FOLLOWING LINE"
5178     PRINT TEXT$
5180     IF INSTR(TEXT$,"DAT") > 0 THEN 5200
5190 NEXT I
5200 I=1: REM Extract PLANES(I) from FILE.DAT
5210 WHILE NOT EOF(1)
5220     LINE INPUT #1,TEXT$
5230     PLANES(I)=MID$(TEXT$,1,12)
5240     MID$(PLANES(I),9,1) = "."
5250     IF LEFT$(PLANES(I),1)="" GOTO 5220
5300     IF MID$(PLANES(I),10,1) <> " " GOTO 5220
5310     IF LEFT$(PLANES(I),8) = "AIRPLANE" GOTO 5220
5320     I=I+1
5330 WEND
5340     NUMFILES=I-2
5350     CLOSE
5360     FOR I=1 TO NUMFILES: REM Remove all blanks from PLANES(I)
5370         ASS$=SPACE$(12)
5380         K=1
5390         FOR J=1 TO 12
5400             T$ = MID$(PLANES(I),J,1)
5410             MID$(ASS$,K,1) = T$
5420             IF T$ <> " " THEN K=K+1
5430         NEXT J
5440         PLANES(I)=ASS$
5450     NEXT I
5460 RETURN *****
5500 CLS: 'SUB TO Display I, AIRFOIL$(I) *****
5510 NP=1
5520 LOCATE 1,30
5530 CLS:PRINT "AIRPLANE FILES"
5540 ROW=3:COLUMN=1
5550 FOR I=NP TO NUMFILES
5560     IF ROW > 18 THEN 5640 '19
5570     LOCATE ROW,COLUMN
5580     PRINT USING "###";I;
5590     PRINT " ";PLANES(I)
5600     COLUMN=COLUMN+16 '20
5610     IF COLUMN > 71 THEN COLUMN=1:ROW=ROW+1 '61
5620 NEXT I
5630 LOCATE 21,1: REM SELECT DATA FILE '21
5640 PRINT "ENTER FILE NUMBER TO LOAD OR E TO EXIT "
5650 PRINT "HIT C TO CHANGE AIRFOIL DATA DISK"
5660 PRINT "HIT ENTER FOR MORE FILES":PRINT
5670 INPUT N$
5680 IF N$ = "E" OR N$="e" THEN N$="E": RETURN
5690 IF N$ = "C" OR N$="c" THEN GOSUB 5000:GOSUB 5100: GOTO 5500
5700 IF N$ = "" THEN NP=NP+80 ELSE 5720
5710 IF NP > NUMFILES THEN 5510 ELSE 5520
5720 N=VAL(N$): IF N < 1 OR N > NUMFILES THEN PRINT "INVALID NUMBER. RE-ENTER.": GOTO 5670

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5730 PRINT: PRINT "YOU HAVE SELECTED      ";PLANES(N);" Y/N.": PRINT
5740 AP$=INKEY$: IF AP$="" GOTO 5740
5750 IF AP$="N" OR AP$="n" GOTO 5500
5760 IF AP$="Y" OR AP$="y" THEN N$=PLANES(N): CLS:
5770 IF N$="E" THEN AIRP$="":GOTO 5220
5775 AIRP$=N$
5780 RETURN '*****
5800 'PATH AND DRIVE SELECT ROUTINE *****
5810 CLS: PRINT: PRINT
5820 PRINT TAB(10);"SELECT DRIVE AND/OR PATH FOR ALL FILE I/O."
5830 PRINT: PRINT TAB(10);"THE DEFAULT DRIVE IS THAT USED TO LOAD PROGRAM."
5840 PRINT: PRINT TAB(10);"HIT D TO CHANGE DRIVE AND PATH."
5850 PRINT: PRINT TAB(10);"HIT ANY OTHER KEY FOR DEFAULT"
5860 AP$=INKEY$: IF AP$="" GOTO 5860
5870 IF AP$="D" OR AP$="d" GOTO 5890
5880 RETURN '-----
5890 GOSUB 5000
5900 CLS: PRINT: PRINT
5910 PRINT: PRINT "CHANGE DRIVE AND PATH.  TYPE EXIT WHEN FINISHED"
5920 SHELL
5930 RETURN '*****
6000 'SUB TO DISPLAY INPUT CONFIGURATION *****
6010 XB=20:YB=20
6020 XC=400:YC=166
6030 LM=LB
6040 IF X2H>LB THEN LM=X2H
6050 IF TP$="Y" THEN 6090
6060 FX=XC/Y1W
6070 FY=YC/Y1W
6080 GOTO 6160
6090 FX=XC/Y2W
6100 FY=YC/Y2W
6110 LMX=INT(FX*(LM+2*Z2V))
6120 WMX=60+LMX
6130 IF WMX=<580 THEN 6160
6140 FX=490/(LM+2*Z2V)
6150 FY=166*FX/400
6160 SCREEN 2:KEY OFF:CLS
6170 GOTO 6390 'AROUND SUBS
6180 'SUB 1 FOR PLOT *****
6190 X=XB+FX*XP
6200 Y=YB+FY*YP
6210 PSET (X,Y)
6220 RETURN
6230 'SUB 2 FOR PLOT *****
6240 X=XB+FX*XP
6250 Y=YB+FY*YP
6260 LINE -(X,Y)
6270 RETURN
6280 ' SUB 3 FOR PLOT.  ELLIPTIC NOSES *****
6290 XP=0:YP=YO
6300 EPS=0
6310 GOSUB 6180
6320 WHILE EPS=<PI/2
6330   XP=XM*(1-COS(EPS))
6340   YP=YO+YM*SQR(2*(XP/XM)-(XP/XM)^2)
6350   GOSUB 6230
6360   EPS=EPS+.025*PI

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6370 WEND
6380 RETURN
6390 ' PLAN VIEW ++++++
6400 XP=0:YP=0
6410 GOSUB 6180
6420 XP=LB:YP=0
6430 GOSUB 6230
6440 XM=X(1)
6450 YO=0
6460 YM=W(1)/2
6470 GOSUB 6280
6480 YM=-YM
6490 GOSUB 6280
6500 XP=X(1):YP=W(1)/2
6510 GOSUB 6180
6520 FOR I=2 TO 8
6530 XP=X(I):YP=W(I)/2
6540 GOSUB 6230
6550 NEXT I
6560 XP=X(1):YP=-W(1)/2
6570 GOSUB 6180
6580 FOR I=2 TO 8
6590 XP=X(I):YP=-W(I)/2
6600 GOSUB 6230
6610 NEXT I
6620 'WING PLAN *****
6630 XP=X1W:YP=0
6640 GOSUB 6180
6650 XP=X3W:YP=Y1W
6660 GOSUB 6230
6670 XP=X4W:YP=Y1W
6680 GOSUB 6230
6690 XP=X2W:YP=0
6700 GOSUB 6230
6710 IF TP$<>"Y" THEN 6800
6720 XP=X3W:YP=Y1W
6730 GOSUB 6180
6740 XP=X5W:YP=Y2W
6750 GOSUB 6230
6760 XP=X6W:YP=Y2W
6770 GOSUB 6230
6780 XP=X4W:YP=Y1W
6790 GOSUB 6230
6800 IF AL$<>"Y" THEN 6870
6810 XP=X4W-ALCR:YP=Y1W
6820 GOSUB 6180
6830 XP=X6W-ALCT:YP=YATP
6840 GOSUB 6230
6850 XP=X6W:YP=YATP
6860 GOSUB 6230
6870 IF HT$<>"Y" THEN 7090
6880 ' HORIZONTAL TAIL *****
6890 XP=X1H:YP=0
6900 GOSUB 6180
6910 XP=X3H:YP=Y1H
6920 GOSUB 6230
6930 XP=X4H:YP=Y1H
6940 GOSUB 6230

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6950 XP=X2H:YP=0
6960 GOSUB 6230
6970 XP=X1H:YP=0
6980 GOSUB 6230
6990 IF HCS="AM" THEN 7040
7000 XP=X2H-CE1:YP=0
7010 GOSUB 6180
7020 XP=X4H-CE2:YP=Y1H
7030 GOSUB 6230
7040 IF COS<>"Y" THEN 7090
7050 XP=X2H-CCO:YP=0
7060 GOSUB 6180
7070 XP=X2H:YP=BCO/2
7080 GOSUB 6230
7090 'FRONT VIEW ++++++
7100 XB=20+FX*(LM+Z2V)+20:YB=20
7110 IF BXS="O" THEN 7160
7120 X1=XB-FX*HB/2:Y1=YB-FY*WB/2
7130 X2=XB+FX*HB/2:Y2=YB+FY*WB/2
7140 LINE (X1,Y1)-(X2,Y2),,B
7150 GOTO 7180
7160 X=XB:Y=YB:R=FX*HB/2
7170 CIRCLE (X,Y),R,,,,.3
7180 'WING FRONT *****
7190 XP=-ZW-TCW1*(X2W-X1W)/2:YP=0
7200 GOSUB 6180
7210 XP=-ZW2-TCW1*(X4W-X3W)/2:YP=Y1W
7220 GOSUB 6230
7230 XP=-ZW2+TCW1*(X4W-X3W)/2:YP=Y1W
7240 GOSUB 6230
7250 XP=-ZW+TCW1*(X2W-X1W)/2:YP=0
7260 GOSUB 6230
7270 IF TP$<>"Y" THEN 7360
7280 XP=-ZW2-TCW1*(X4W-X3W)/2:YP=Y1W
7290 GOSUB 6180
7300 XP=-ZW3-TCW2*(X6W-X5W)/2:YP=Y2W
7310 GOSUB 6230
7320 XP=-ZW3+TCW2*(X6W-X5W)/2:YP=Y2W
7330 GOSUB 6230
7340 XP=-ZW2+TCW1*(X4W-X3W)/2:YP=Y1W
7350 GOSUB 6230
7360 'TAILS *****
7370 IF HT$<>"Y" THEN 7430
7380 IF VTL$="Y" THEN 7490
7390 XP=-ZH:YP=0
7400 GOSUB 6180
7410 XP=-ZH:YP=Y1H
7420 GOSUB 6230
7430 ' VERT. TAIL *****
7440 XP=-Z1V:YP=0
7450 GOSUB 6180
7460 XP=-Z2V:YP=0
7470 GOSUB 6230
7480 GOTO 7540
7490 ' VEE-TAIL *****
7500 XP=-ZH:YP=0
7510 GOSUB 6180
7520 XP=-Z2V:YP=Y1H

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7530 GOSUB 6230
7540 ' SIDE VIEW ++++++
7550 FY=-FY:FX=-FX
7560 XB=XB-FX*Z2V+20
7570 YB=180
7580 ' BODY SIDE *****
7590 XP=0:YP=0
7600 GOSUB 6180
7610 XP=0:YP=LB
7620 GOSUB 6230
7630 XP=ZBN:YP=0
7640 GOSUB 6180
7650 YM=X(1)
7660 XO=ZBN
7670 XM=H(1)/2-ZBN
7680 EPS=0
7690 WHILE EPS<PI/2
7700   YP=YM*(1-COS(EPS))
7710   XP=XO+XM*SQR(2*(YP/YM)-(YP/YM)^2)
7720   GOSUB 6230
7730   EPS=EPS+.025*PI
7740 WEND
7750 XP=ZBN:YP=0
7760 GOSUB 6180
7770 XM=-H(1)/2+ZBN
7780 EPS=0
7790 WHILE EPS<PI/2
7800   YP=YM*(1-COS(EPS))
7810   XP=XO+XM*SQR(2*(YP/YM)-(YP/YM)^2)
7820   GOSUB 6230
7830   EPS=EPS+.025*PI
7840 WEND
7850 BB=(ZBB+H(8)/2-H(4)/2)/(X(8)-X(4))
7860 AB=H(4)/2-BB*X(4)
7870 XP=H(1)/2:YP=X(1)
7880 GOSUB 6180
7890 XP=H(2)/2:YP=X(2)
7900 GOSUB 6230
7910 XP=H(3)/2:YP=X(3)
7920 GOSUB 6230
7930 XP=H(4)/2:YP=X(4)
7940 GOSUB 6230
7950 XP=AB+BB*X(5):YP=X(5)
7960 GOSUB 6230
7970 XP=AB+BB*X(6):YP=X(6)
7980 GOSUB 6230
7990 XP=AB+BB*X(7):YP=X(7)
8000 GOSUB 6230
8010 XP=AB+BB*X(8):YP=X(8)
8020 GOSUB 6230
8030 XP=AB+BB*X(8)-H(8):YP=X(8)
8040 GOSUB 6230
8050 XP=-H(1)/2:YP=X(1)
8060 GOSUB 6180
8070 XP=-H(2)/2:YP=X(2)
8080 GOSUB 6230
8090 XP=-H(3)/2:YP=X(3)
8100 GOSUB 6230

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8110 XP=-H(4)/2:YP=X(4)
8120 GOSUB 6230
8130 XP=AB+BB*X(5)-H(5):YP=X(5)
8140 GOSUB 6230
8150 XP=AB+BB*X(6)-H(6):YP=X(6)
8160 GOSUB 6230
8170 XP=AB+BB*X(7)-H(7):YP=X(7)
8180 GOSUB 6230
8190 XP=AB+BB*X(8)-H(8):YP=X(8)
8200 GOSUB 6230
8210 'WING ROOT
8220 XP=ZW+(CRW/4)*TAN(PI*IWD/180):YP=X1W
8230 GOSUB 6180
8240 XP=ZW-(3*CRW/4)*TAN(PI*IWD/180):YP=X2W
8250 GOSUB 6230
8260 IF VTL$="Y" THEN 8490
8270 'V.TAIL *****
8280 XP=Z1V:YP=X1V
8290 GOSUB 6180
8300 XP=Z2V:YP=X3V
8310 GOSUB 6230
8320 XP=Z2V:YP=X4V
8330 GOSUB 6230
8340 XP=Z1V:YP=X2V
8350 GOSUB 6230
8360 XP=Z1V:YP=X1V
8370 GOSUB 6230
8380 XP=Z2V:YP=X4V-CRTP
8390 GOSUB 6180
8400 XP=Z2V-BR:YP=X2V-CRRT
8410 GOSUB 6230
8420 'H. TAIL
8430 IF HT$(">"Y" THEN 8580
8440 XP=ZH:YP=X1H
8450 GOSUB 6180
8460 XP=ZH:YP=X2H
8470 GOSUB 6230
8480 GOTO 8580
8490 'VEE TAIL *****
8500 XP=ZH:YP=X1H
8510 GOSUB 6180
8520 XP=Z2V:YP=X3H
8530 GOSUB 6230
8540 XP=Z2V:YP=X4H
8550 GOSUB 6230
8560 XP=ZH:YP=X2H
8570 GOSUB 6230
8580 PRINT AIRP$ 'PRINT AIRPLANE NAME *****
8590 DEF FNX=Y+600:DEF FNY=150-X
8600 FOR X=0 TO 70
8610   FOR Y=0 TO 7
8620     DOT=POINT(X,Y):IF DOT=0 THEN 8640
8630     PSET (FNX,FNY),DOT
8640   NEXT Y,X
8650 HLD$=INKEY$:IF HLD$="" THEN 8650
8660 CLS:SCREEN 0:KEY ON
8670 RETURN
9000 'TO PRINT INPUT DIMENSIONS TABLE

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9030 LPRINT TAB(12);"INPUT DIMENSIONS FOR _____"
9040 LPRINT
9050 LPRINT TAB(12);"WING OR IN'R PANEL";TAB(36);"HORIZ. TAIL";TAB(60);"VERT. TAIL"
9060 LPRINT
9070 LPRINT TAB(12);"ROOT L.E.X";TAB(24);"____";TAB(36);"ROOT L.E.X";TAB(48);"____";TAB(60);"Z.R'T. : HRL";TAB(72);"____"
9080 LPRINT TAB(12);"ROOT T.E.X";TAB(24);"____";TAB(36);"ROOT T.E.X";TAB(48);"____";TAB(60);"ROOT L.E.X";TAB(72);"____"
9090 LPRINT TAB(12);"TIP Y-STN.";TAB(24);"____";TAB(36);"TIP Y-STN";TAB(48);"____";TAB(60);"ROOT T.E.X";TAB(72);"____"
9100 LPRINT TAB(12);"TIP L.E.X";TAB(24);"____";TAB(36);"TIP L.E.X";TAB(48);"____";TAB(60);"Z.T'P : HRL";TAB(72);"____"
9110 LPRINT TAB(12);"TIP T.E.X";TAB(24);"____";TAB(36);"TIP T.E.X";TAB(48);"____";TAB(60);"TIP L.E.X";TAB(72);"____"
9120 LPRINT TAB(12);"Z. @ CR/4";TAB(24);"____";TAB(36);"H. H'T : HRL";TAB(48);"____";TAB(60);"TIP T.E.X";TAB(72);"____"
9130 LPRINT TAB(12);"TIP Z. : HRL";TAB(24);"____";TAB(36);"THICK. T/C";TAB(48);"____";TAB(60);"THICK. T/C";TAB(72);"____"
9140 LPRINT TAB(12);"THICK. T/C";TAB(24);"____";TAB(36);"ELE. R'T C.";TAB(48);"____";TAB(60);"RUD'R SPAN";TAB(72);"____"
9150 LPRINT TAB(36);"ELE. T'P C.";TAB(48);"____";TAB(60);"RUD'R R'T C.";TAB(72);"____"
9160 LPRINT TAB(12);"OUT'R PANEL OR AIL.";TAB(36);"CUT O'T SPAN";TAB(48);"____";TAB(60);"RUD'R TIP C.";TAB(72);"____"
9170 LPRINT TAB(36);"CUT O'T CHD.";TAB(48);"____"
9180 LPRINT TAB(12);"TIP Y-STN.";TAB(24);"____"
9190 LPRINT TAB(12);"TIP L.E.X";TAB(24);"____"
9200 LPRINT TAB(12);"TIP T.E.X";TAB(24);"____"
9210 LPRINT TAB(12);"TIP Z. : HRL";TAB(24);"____"
9220 LPRINT TAB(12);"AVG T/C";TAB(24);"____"
9230 LPRINT TAB(12);"AIL. R'T CHD";TAB(24);"____"
9240 LPRINT TAB(12);"AIL. Y-TIP";TAB(24);"____"
9250 LPRINT TAB(12);"AIL. TIP C.";TAB(24);"____"
9260 LPRINT
9270 LPRINT TAB(12);"BODY"
9280 LPRINT
9290 LPRINT TAB(12);"LENGTH";TAB(24);"____";TAB(36);"STATION";TAB(60);"HEIGHT";TAB(72);"WIDTH"
9300 LPRINT TAB(12);"Z NOSE : HRL";TAB(24);"____";TAB(36);"NOSE";TAB(60);"____";TAB(72);"____"
9310 LPRINT TAB(12);"Z TAIL : HRL";TAB(24);"____";TAB(36);"1/4 TH LENGTH";TAB(60);"____";TAB(72);"____"
9320 LPRINT TAB(12);"MAX H'T.";TAB(24);"____";TAB(36);"WING R'T L.E.";TAB(60);"____";TAB(72);"____"
9330 LPRINT TAB(12);"MAX W'TH.";TAB(24);"____";TAB(36);"WING R'T 1/4 CH'D";TAB(60);"____";TAB(72);"____"
9340 LPRINT TAB(12);"SQR OR OVAL";TAB(24);"____";TAB(36);"WING R'T T.E.";TAB(60);"____";TAB(72);"____"
9350 LPRINT TAB(36);"HALF LENGTH";TAB(60);"____";TAB(72);"____"
9360 LPRINT TAB(36);"THREE-QUARTER LENGTH";TAB(60);"____";TAB(72);"____"
9370 LPRINT TAB(36);"V. TAIL R'T 1/4 CHD";TAB(60);"____";TAB(72);"____"
9380 LPRINT TAB(36);"BODY TAIL";TAB(60);"____";TAB(72);"____"
9390 LPRINT
9400 LPRINT TAB(12);"ADDITIONAL FOR STAB & CONT"
9410 LPRINT
9420 LPRINT TAB(12);"RN PER IN.";TAB(24);"____";TAB(60);"AIRFOIL";TAB(68);"____"
9430 LPRINT
9440 LPRINT TAB(36);"WING";TAB(48);"H. TAIL";TAB(60);"AIRF AOL";TAB(72);"____"
9450 LPRINT TAB(12);"TRANSITION X/C";TAB(36);"____";TAB(48);"____";TAB(60);"AIRF CL/RAD";TAB(72);"____"
9460 LPRINT TAB(12);"1/2 T.E. SLOPE";TAB(36);"____";TAB(48);"____";TAB(60);"AIRF CMO";TAB(72);"____"
9470 LPRINT TAB(12);"INCIDENCE (DEG.)";TAB(36);"____";TAB(48);"____";TAB(60);"AIRF MIN CD";TAB(72);"____"
9480 LPRINT CHR$(12)
9490 RETURN '-----
10000 'INPUT SUBROUTINES -----
10010 PRINT " WING OR INNER PANEL DIMENSIONS" '-----
10020 PRINT
10030 INPUT "ROOT L.E. X-STN. _____",X1W
10040 RETURN
10050 INPUT "ROOT T.E. X-STN. _____",X2W
10060 RETURN
10070 INPUT "TIP Y-STN. _____",Y1W
10080 RETURN
10090 INPUT "TIP L.E. X-STN. _____",X3W
10100 RETURN

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10110 INPUT "TIP T.E. X-STN. _____" ",X4W
10120 RETURN
10130 INPUT "HT. OF WRP ABOVE HRL AT WING C-ROOT/4 _____" ",ZW
10140 RETURN
10150 INPUT "WING OR INNER PANEL TIP HT. ABOVE HRL _____" ",ZW2
10160 RETURN
10170 INPUT "WING OR INNER PANEL THICKNESS RATIO _____" ",TCW1
10180 PRINT
10190 RETURN '-----
10200 PRINT " OUTER PANEL DIMENSIONS" '-----
10210 PRINT
10220 INPUT "TIP Y-STN. _____" ",Y2W
10230 RETURN
10240 INPUT "TIP L.E. X-STN. _____" ",X5W
10250 RETURN
10260 INPUT "TIP T.E. X-STN. _____" ",X6W
10270 RETURN
10280 INPUT "OUTER PANEL TIP HT. ABOVE HRL _____" ",ZW3
10290 RETURN
10300 INPUT "OUTER PANEL AVG. THICKNESS RATIO _____" ",TCW2
10301 PRINT
10310 RETURN '-----
10320 'AILERON DIMENSIONS -----
10330 INPUT "AILERON ROOT CHORD _____" ",ALCR
10340 RETURN
10350 INPUT "AIL. TIP Y-STN. _____" ",YATP
10360 RETURN
10370 INPUT "AILERON TIP CHORD _____" ",ALCT
10380 PRINT
10390 RETURN '-----
10400 PRINT " HORIZONTAL TAIL DIMENSIONS" '-----
10410 PRINT
10420 INPUT "ROOT L.E. X-STN. _____" ",X1H
10430 RETURN
10440 INPUT "ROOT T.E. X-STN. _____" ",X2H
10450 RETURN
10460 INPUT "TIP Y-STN. _____" ",Y1H
10470 RETURN
10480 INPUT "TIP L.E. X-STN _____" ",X3H
10490 RETURN
10500 INPUT "TIP T.E. X-STN _____" ",X4H
10510 RETURN
10520 INPUT "HEIGHT FROM HRL _____" ",ZH
10530 RETURN
10540 INPUT "HORIZ. TAIL THICKNESS RATIO _____" ",TCH
10541 PRINT
10550 RETURN
10560 INPUT "ELEVATOR ROOT CHORD AT CENTER LINE _____" ",CE1
10570 RETURN
10580 INPUT "ELEVATOR TIP CHORD _____" ",CE2
10581 PRINT
10590 RETURN
10600 INPUT "HORIZ. TAIL CUT-OUT SPAN AT T.E. _____" ",BCO
10610 RETURN
10620 INPUT "HORIZ. TAIL CUT-OUT CHORD AT CENT. LINE _____" ",CCO
10630 PRINT
10640 RETURN '-----
10650 PRINT " VERTICAL TAIL DIMENSIONS" '-----

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10660 PRINT
10680 INPUT "HEIGHT OF VERT. ROOT ABOVE HRL _____" ",Z1V
10690 RETURN
10700 INPUT "ROOT L.E. X-STN. _____" ",X1V
10710 RETURN
10720 INPUT "ROOT T.E. X-STN. _____" ",X2V
10730 RETURN
10740 INPUT "HEIGHT OF VERT. TIP ABOVE HRL _____" ",Z2V
10750 RETURN
10760 INPUT "TIP L.E. X-STN. _____" ",X3V
10770 RETURN
10780 INPUT "TIP T.E. X-STN. _____" ",X4V
10790 RETURN
10800 INPUT "VERT. TAIL THICKNESS RATIO _____" ",TCV
10810 RETURN
10820 INPUT "RUDDER SPAN _____" ",BR
10830 RETURN
10840 INPUT "RUDDER ROOT CHORD _____" ",CRRT
10850 RETURN
10860 INPUT "RUDDER TIP CHORD _____" ",CRTP
10870 PRINT
10880 RETURN '-----
10890 PRINT " BODY DIMENSIONS" '-----
10900 PRINT
10910 INPUT "BODY LENGTH _____" ",LB
10920 RETURN
10930 INPUT "VERT. DIST. FROM HRL TO BODY NOSE _____" ",ZBN
10940 RETURN
10950 INPUT "VERT. DIST. FROM HRL TO BODY TAIL _____" ",ZBB
10960 RETURN
10970 INPUT "MAX. BODY HEIGHT _____" ",HB
10980 RETURN
10990 INPUT "MAX. BODY WIDTH _____" ",WB
11000 RETURN
11010 PRINT
11020 PRINT " ENTER THE BODY HEIGHT AND WIDTH AT THE INDICATED STNS."
11030 PRINT " SEPERATE NUMBERS INPUT BY COMMAS"
11040 PRINT
11050 INPUT " H AND W, AT 1/4 BODY L. _____" ",H25L,W25L
11060 INPUT " H AND W AT WING L.E. _____" ",H1W,W1W
11070 INPUT " H AND W AT WING ROOT 1/4 CHD. _____" ",HRTW4,WRTW4
11080 INPUT " H AND W AT WING T.E. _____" ",H2W,W2W
11090 INPUT " H AND W AT 1/2 BODY LENGTH _____" ",H5L,W5L
11100 INPUT " H AND W AT 3/4 BODY LENGTH _____" ",H75L,W75L
11110 INPUT " H AND W AT 1/4 VERT. ROOT CHORD _____" ",HRTV4,WRTV4
11120 INPUT " H AND W AT BODY TAIL _____" ",HL,WL
11130 PRINT
11140 RETURN '-----
11150 PRINT
11160 PRINT " STABILITY AND CONTROL DATA" '-----
11170 PRINT
11180 PRINT " INPUTS WITH (D) SHOWN HAVE A DEFAULT VALUE. HIT RETURN KEY"
11190 PRINT
11200 INPUT " REYNOLDS NUMBER PER INCH (D=20000) _____" ",RNIN$
11210 RNIN=VAL(RNIN$):IF RNIN$="" THEN RNIN=20000
11220 RETURN
11230 INPUT " TRANSITION PT. X/C ON WING (D=.50) _____" ",XTRW$
11240 XTRW=VAL(XTRW$): IF XTRW$="" THEN XTRW=.5

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11250 RETURN
11260 INPUT " TRANSITION PT. X/C ON HORIZ. TAIL (D=.5) _____ ",XTRH$
11270 XTRH=VAL(XTRH$): IF XTRH$="" THEN XTRH=.5
11280 RETURN
11290 INPUT " WING AIRFOIL 1/2 THICKNESS T.E. SLOPE (POS.) _____ ",TEPSW
11300 RETURN
11310 INPUT " HORIZ. TAIL 1/2 THICK. T.E. SLOPE (POS.) (D=T/C) _____ ",TEPSH$
11320 TEPSH=VAL(TEPSH$):IF TEPSH$="" THEN TEPSH=TCH
11330 RETURN
11340 INPUT " WING INCIDENCE FROM HRL TO ROOT AIRF. CH'D PLANE _____ ",IWD
11350 RETURN
11360 INPUT " H. TAIL INCIDENCE FROM HRL _____ ",IHD
11370 RETURN
11380 INPUT " WING ANGLE OF ZERO LIFT FROM AIRF. RT. CH'D PLANE _____ ",ALOWA
11390 RETURN
11400 INPUT " AIRF. 2-DIM. LIFT CURVE SLOPE (D=CALC) PER RAD. _____ ",AOTW$
11405 AOTW=VAL(AOTW$):IF AOTW$="" THEN AOTW=0
11410 RETURN
11420 INPUT " AIRF. ZERO LIFT PITCHING MOMENT COEFF. _____ ",CMOA
11430 RETURN
11440 INPUT " W. ROOT AIRF. ZERO LIFT DRAG COEFF. _____ ",CDOW
11450 PRINT
11460 RETURN '-----'
12000 'SUB TO RESCALE INPUT DIMENSIONS -----'
12010 PRINT
12020 INPUT " SCALE FACTOR _____ ",FS
12040 IF FS= 1! THEN RETURN
12050 X1W=FS*X1W:X2W=FS*X2W:Y1W=FS*Y1W:X3W=FS*X3W:X4W=FS*X4W:ZW=FS*ZW
12060 ZW2=FS*ZW2:Y2W=FS*Y2W:X5W=FS*X5W:X6W=FS*X6W:ZW3=FS*ZW3:ALCR=FS*ALCR
12070 YATP=FS*YATP:ALCT=FS*ALCT:X1H=FS*X1H:X2H=FS*X2H:Y1H=FS*Y1H:X3H=FS*X3H
12080 X4H=FS*X4H:ZH=FS*ZH:CE1=FS*CE1:CE2=FS*CE2:BCO=FS*BCO:CCO=FS*CCO
12090 Z1V=FS*Z1V:X1V=FS*X1V:X2V=FS*X2V:Z2V=FS*Z2V:X3V=FS*X3V:X4V=FS*X4V
12100 BR=FS*BR:CRRT=FS*CRRT:CRTP=FS*CRTP:LB=FS*LB:ZBN=FS*ZBN:ZBB=FS*ZBB
12110 HB=FS*HB:WB=FS*WB:H25L=FS*H25L:W25L=FS*W25L:H1W=FS*H1W:W1W=FS*W1W
12120 HRTW4=FS*HRTW4:WRTW4=FS*WRTW4:H2W=FS*H2W:W2W=FS*W2W:H5L=FS*H5L
12130 W5L=FS*W5L:H75L=FS*H75L:W75L=FS*W75L:HRTV4=FS*HRTV4:WRTV4=FS*WRTV4
12140 HL=FS*HL:WL=FS*WL:RNIN=RNIN/FS
12150 RETURN '-----'
14000 'PRINT DIMENSIONAL INPUT DATA -----'
14020 LPRINT " INPUT DIMENSIONS FOR ";AIRP$
14030 LPRINT
14040 LPRINT SPC(4);"WING OR IN'R PANEL";SPC(8);"HORIZ. TAIL";SPC(15);"VERT. TAIL"
14050 LPRINT
14060 LPRINT USING " ROOT L.E.X ###.###";X1W;
14070 LPRINT USING " ROOT L.E.X ###.###";X1H;
14080 LPRINT USING " Z.R'T FROM HRL ###.###";Z1V
14090 LPRINT USING " ROOT T.E.X ###.###";X2W;
14100 LPRINT USING " ROOT T.E.X ###.###";X2H;
14110 LPRINT USING " ROOT L.E.X ###.###";X1V
14120 LPRINT USING " TIP Y-STN. ###.###";Y1W;
14130 LPRINT USING " TIP Y-STN. ###.###";Y1H;
14140 LPRINT USING " ROOT T.E.X ###.###";X2V
14150 LPRINT USING " TIP L.E.X ###.###";X3W;
14160 LPRINT USING " TIP L.E.X ###.###";X3H;
14170 LPRINT USING " Z.T'P FROM HRL ###.###";Z2V
14180 LPRINT USING " TIP T.E.X ###.###";X4W;
14190 LPRINT USING " TIP T.E.X ###.###";X4H;
14200 LPRINT USING " TIP L.E.X ###.###";X3V

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14210 LPRINT USING " Z AT CR'T/4 ###.###;ZW;
14220 LPRINT USING " H.H'T FROM HRL ###.###;ZH;
14230 LPRINT USING " TIP T.E.X ###.###;X4V
14240 LPRINT USING " TIP Z FROM HRL ###.###;ZW2;
14250 LPRINT USING " THICK. T/C ###.###;TCH;
14260 LPRINT USING " THICK. T/C ###.###;TCV
14270 LPRINT USING " THICK. T/C ###.###;TCW1;
14280 LPRINT USING " ELEV. R'T C. ###.###;CE1;
14290 LPRINT USING " RUD'R SPAN ###.###;BR
14300 LPRINT SPC(26);
14310 LPRINT USING " ELEV. T'P C. ###.###;CE2;
14320 LPRINT USING " RUD. R'T C. ###.###;CRRT
14330 LPRINT SPC(4);"OUT'R PANEL OR AIL. ";
14340 LPRINT USING " CUT OUT SPAN ###.###;BCO;
14350 LPRINT USING " RUD'R TIP C. ###.###;CRTP
14360 LPRINT SPC(26);
14370 LPRINT USING " CUT OUT CHD. ###.###;CCO
14380 LPRINT
14390 LPRINT USING " TIP Y-STN. ###.###;Y2W
14400 LPRINT USING " TIP L.E.X ###.###;X5W
14410 LPRINT USING " TIP T.E.X ###.###;X6W
14420 LPRINT USING " TIP Z FROM HRL ###.###;ZW3
14430 LPRINT USING " AVG. T/C ###.###;TCW2
14440 LPRINT USING " AIL. R'T CHD ###.###;ALCR
14450 LPRINT USING " AIL. Y-TIP ###.###;YATP
14460 LPRINT USING " AIL. TIP CHD ###.###;ALCT
14470 LPRINT
14480 LPRINT SPC(4);"BODY"
14490 LPRINT
14500 LPRINT USING " LENGTH ###.###;LB;
14510 LPRINT SPC(4);"STATION";SPC(19);"HEIGHT";SPC(8);"WIDTH"
14520 LPRINT USING " Z NOSE FR. HRL ###.###;ZEN;
14530 LPRINT SPC(4);"NOSE";SPC(23);"0.0";SPC(11);"0.0"
14540 LPRINT USING " Z TAIL FR. HRL ###.###;ZBB;
14550 LPRINT SPC(4);"1/4 TH LENGTH ";
14560 LPRINT USING " ###.###;H25L,W25L
14570 LPRINT USING " MAX. H'T ###.###;HB;
14580 LPRINT SPC(4);"WING R'T L.E. ";
14590 LPRINT USING " ###.###;H1W,W1W
14600 LPRINT USING " MAX. W'TH ###.###;WB;
14610 LPRINT SPC(4);"WING R'T 1/4TH CHD";
14620 LPRINT USING " ###.###;HRTW4,WRTW4
14630 LPRINT SPC(4);"SQR OR OVAL ";BXS\$;
14640 LPRINT SPC(7);"WING R'T T.E. ";
14650 LPRINT USING " ###.###;H2W,W2W
14660 LPRINT SPC(30);"HALF LENGTH ";
14670 LPRINT USING " ###.###;H5L,W5L
14680 LPRINT SPC(30);"3/4TH LENGTH ";
14690 LPRINT USING " ###.###;H75L,W75L
14700 LPRINT SPC(30);"VERT. R,T 1/4 CHD ";
14710 LPRINT USING " ###.###;HRTV4,WRTV4
14720 LPRINT SPC(30);"BODY TAIL ";
14730 LPRINT USING " ###.###;HL,WL
14740 LPRINT
14750 LPRINT SPC(4);"ADDITIONAL FOR STAB & CONT."
14760 LPRINT
14770 LPRINT USING " RN PER IN. #####;RNIR;
14780 LPRINT SPC(30);"AIRFOIL ";AF\$

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14790 LPRINT
14800 LPRINT SPC(30);"WING      H. TAIL";
14810 LPRINT USING "      AIRF AOL      ###.###";ALOWA
14820 LPRINT SPC(4);"TRANSITION X/C      ";
14830 LPRINT USING "      ###.###";XTRW,XTRH;
14840 LPRINT USING "      AIRF CL/RAD ###.###";AOTW
14850 LPRINT SPC(4);"1/2 T.E. SLOPE (POS)";
14860 LPRINT USING "      ###.###";TEPSW,TEPSH;
14870 LPRINT USING "      AIRF CMO      ###.###";CMOA
14880 LPRINT SPC(4);"INCIDENCE (DEG)      ";
14890 LPRINT USING "      ###.###";IWD,IHD;
14900 LPRINT USING "      AIRF MIN. CD ###.###";CDOW
14910 LPRINT
14920 LPRINT SPC(4);"CONFIGURATION DEFINITION"
14930 LPRINT
14940 LPRINT SPC(4);"OUTER WING PANEL      ";TP$
14950 LPRINT SPC(4);"AILERON      ";AL$
14960 LPRINT SPC(4);"HORIZONTAL TAIL      ";HT$
14970 LPRINT SPC(4);"      VEE TAIL      ";VTL$
14980 LPRINT SPC(4);"      ALL-MOVE. OR ELEV.      ";HC$
14990 LPRINT SPC(4);"      TAIL T.E. CUT-OUT      ";CO$
15000 LPRINT CHR$(12)
15010 RETURN '-----
20000 'WING OR INNER PANEL DIMENSIONS -----
20010 CRW=X2W-X1W
20020 C2W=X4W-X3W
20030 LAM1=C2W/CRW
20040 LAMS1=1+LAM1
20050 MAC1=(2*CRW*(LAMS1-(LAM1/LAMS1)))/3
20060 YBAR1=(Y1W*(1+2*LAM1))/(3*LAMS1)
20070 S1=(CRW+C2W)*Y1W/2
20080 TNO1=(X3W-X1W)/Y1W
20090 XOBR1=YBAR1*TNO1
20100 BW=2*Y1W
20110 SW=2*S1
20120 ARW=(BW^2)/SW
20130 LAMW=LAM1
20140 MACW=MAC1
20150 YBARW=YBAR1
20160 XOBRW=X1W+XOBR1
20170 XC4W=XOBRW+MACW/4
20180 XTPLE=X3W
20190 CTW=C2W
20200 GAM1=ATN((ZW2-ZW)/Y1W)*180/PI
20210 GAM2=GAM1
20220 RETURN '-----
20230 'OUTER PANEL AND/OR AILERON DIMENSIONS -----
20240 C3W=X6W-X5W
20250 LAM2=C3W/C2W
20260 LAMS2=1+LAM2
20270 MAC2=(2*C2W*(LAMS2-(LAM2/LAMS2)))/3
20280 BPM2=Y2W-Y1W
20290 S2=(C3W+C2W)*BPM2/2
20300 TNO2=(X5W-X3W)/BPM2
20310 STOT=S1+S2
20320 MACW=(S1*MAC1+S2*MAC2)/STOT
20330 YBAR2=(BPM2*(1+2*LAM2))/(3*LAMS2)
20340 YBARW=(YBAR1*S1+(Y1W+YBAR2)*S2)/STOT

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20350 XOB $BRW = (XOBR1 * S1 + (Y1W * TNO1 + YBAR2 * TNO2) * S2) / STOT$ 
20360 XOB $BRW = XOB $BRW + X1W$ 
20370 XC4 $W = XOB $BRW + MACW / 4$ 
20380 XTPLE $= X5W$ 
20390 CTW $= C3W$ 
20400 BW $= 2 * Y2W$ 
20410 SW $= 2 * STOT$ 
20420 ARW $= (BW^2) / SW$ 
20430 SCB $= STOT / (MACW * Y2W)$ 
20440 BLAM $= (6 - 4 * SCB) / (3 - 4 * SCB)$ 
20450 BLAM $= -BLAM / 2$ 
20460 RLAM $= SQR(BLAM^2 - 1)$ 
20470 LAMW $= BLAM - RLAM$ 
20480 GAM2 $= ATN((ZW3 - ZW2) / (Y2W - Y1W)) * 180 / PI$ 
20490 RETURN '-----'
20500 'HORIZONTAL TAIL DIMENSIONS -----'
20510 BH $= 2 * Y1H$ 
20520 CRH $= X2H - X1H$ 
20530 CTH $= X4H - X3H$ 
20540 LAMH $= CTH / CRH$ 
20550 LAMHS $= 1 + LAMH$ 
20560 SH $= (CRH + CTH) * BH / 2$ 
20570 ARH $= (BH^2) / SH$ 
20580 MACH $= (2 * CRH * (LAMHS - (LAMH / LAMHS))) / 3$ 
20590 YBARH $= (Y1H * (1 + 2 * LAMH)) / (3 * LAMHS)$ 
20600 TNOH $= (X3H - X1H) / Y1H$ 
20610 XOH $= X1H + YBARH * TNOH$ 
20620 XC4H $= XOH + MACH / 4$ 
20630 LH $= XC4H - XC4W$ 
20640 LRH $= LH / MACW$ 
20650 SRH $= SH / SW$ 
20660 HVOL $= LRH * SRH$ 
20670 TNC4 $= TNOH - (1 - LAMH) / (ARH * (LAMHS))$ 
20680 SP4H $= ATN(TNC4) * 180 / PI$ 
20690 SE $= (CE1 + CE2) * Y1H$ 
20700 CECH $= SE / SH$ 
20710 IF HCS $= "AM"$  THEN CECH $= 1!$ 
20720 RETURN '-----'
20730 'VERTICAL TAIL DIMENSIONS -----'
20740 IF ZH $> Z1V$  THEN HH $\$ = "HONV"$  ELSE HH $\$ = "HONB"$ 
20750 BV $= Z2V - Z1V$ 
20760 CRV $= X2V - X1V$ 
20770 CTV $= X4V - X3V$ 
20780 LAMV $= CTV / CRV$ 
20790 LAMVS $= 1 + LAMV$ 
20800 SV $= (CRV + CTV) * BV / 2$ 
20810 AREV $= 2 * ((BV^2) / SV)$ 
20820 MACV $= (2 * CRV * (LAMVS - (LAMV / LAMVS))) / 3$ 
20830 YBARV $= (BV * (1 + 2 * LAMV)) / (3 * LAMVS)$ 
20840 TNOV $= (X3V - X1V) / BV$ 
20850 XOV $= X1V + YBARV * TNOV$ 
20860 XC4V $= XOV + MACV / 4$ 
20870 LV $= XC4V - XC4W$ 
20880 LRV $= LV / BW$ 
20890 SRV $= SV / SW$ 
20900 VVOL $= LRV * SRV$ 
20910 SR $= (CRRT + CRTP) * BR / 2$ 
20920 CRCV $= SR / SV$$$ 
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20930 XRTV4=X1V+CRV/4
20940 XTPV4=X3V+CTV/4
20950 TNC4V=(XTPV4-XRTV4)/BV
20960 SP4V=ATN(TNC4V)*180/PI
20970 RETURN '-----
20980 'SORT OUT BODY H AN W DIMENSIONS -----
21010 X(1)=LB/4:H(1)=H25L:W(1)=W25L
21020 X(2)=X1W:H(2)=H1W:W(2)=W1W
21030 XRTW4=X1W+CRW/4
21040 X(3)=XRTW4:H(3)=HRTW4:W(3)=WRTW4
21050 X(4)=X2W:H(4)=H2W:W(4)=W2W
21060 X(5)=LB/2:H(5)=H5L:W(5)=W5L
21070 X(6)=3*LB/4:H(6)=H75L:W(6)=W75L
21080 X(7)=XRTV4:H(7)=HRTV4:W(7)=WRTV4
21090 X(8)=LB:H(8)=HL:W(8)=WL
21100 FOR I=0 TO 7
21110 IF X(I)<X(I+1) THEN 21130
21120 SWAP X(I),X(I+1):SWAP H(I),H(I+1):SWAP W(I),W(I+1)
21130 NEXT I
21140 RETURN '-----
21150 'BODY DIMENSIONS -----
21160 SB=PI*X(1)*W(1)/4
21170 SBF=SB
21180 SBP=PI*X(1)*H(1)/4
21190 FOR I=2 TO 8
21200 SB=SB+(W(I)+W(I-1))*(X(I)-X(I-1))/2
21210 IF X(I) > XRTW4 THEN 21230
21220 SBF=SB
21230 SBP=SBP+(H(I)+H(I-1))*(X(I)-X(I-1))/2
21240 NEXT I
21250 NB=LB-X2W
21260 IF BXS$="S" THEN 21280
21270 SXS=PI*HRTW4*WRTW4/4:GOTO 21290
21280 SXS=HRTW4*WRTW4
21290 BVOL=LB*SXS/(BW*SW)
21300 DZB=ZBB-ZW
21310 DB=SQR(4*SXS/PI)
21320 BLD=LB/DB
21330 IF BXS$="S" THEN 21520 'START BODY S-WET
21340 FOR I=1 TO 7
21350 BHW1=(H(I)+W(I))/2
21360 BHW2=(H(I)-W(I))/2
21370 BRR=BHW2/BHW1
21380 BPRM(I)=PI*BHW1*(64-3*BRR^4)/(64-16*BRR^2)
21390 NEXT I
21400 BPRM(8)=2*(W(8)+H(8))
21410 B=BPRM(1)/(2*PI)
21420 A=X(1)
21430 E=(SQR(A*A-B*B))/A
21440 IF E=1 THEN TH=PI/2 ELSE 21460
21450 GOTO 21470
21460 TH=ATN(E/(SQR(1-E*E)))
21470 BSWT=PI*B*(B+A*TH/E)
21480 FOR I=2 TO 8
21490 BSWT=BSWT+(BPRM(I)+BPRM(I-1))*(X(I)-X(I-1))/2
21500 NEXT I
21510 GOTO 21530
21520 BSWT=2*(SB+SBP)

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21530 RETURN '-----
22000 'V-TAIL DIMENSIONS -----
22010 ZVT=Z2V:HH$="HONB"
22020 Y1H=SQR(Y1H*Y1H+ZVT*ZVT)
22030 GAMVT=ATN(ZVT/Y1H)
22040 GOSUB 20500 'H. TAIL DIMS.
22050 Z1V=ZH:X1V=X1H:X2V=X2H:X3V=X3H:X4V=X4H:TCV=TCH:CRRT=CE1:CRTP=CE2
22060 BR=Y1H/2:BV=Y1H*SIN(GAMVT):CRV=CRH:CTV=CTH:LAMV=LAMH:LAMVS=LAMHS
22070 SV=SH:AREV=ARH:MACV=MACH:YBARV=YBARH*SIN(GAMVT):TNOV=TNOH
22080 XOV=XOH:XC4V=XC4H:LV=LH:LRV=LV/BW:SRV=SV/SW:VVOL=LRV*SRV*SIN(GAMVT)
22090 SR=SE:CRCV=CECH:XRTV4=X1V+CRV/4:XTPV4=X3V+CTV/4:TNC4V=TNC4:SP4V=SP4H
22100 RETURN '-----
30000 'STABILITY AND CONTROL CALCULATIONS -----
30010 'ANGLE OF ZERO LIFT -----
30020 ALOWD=ALOWA-IWD
30030 ALOW=ALOWD*PI/180
30040 ' 2-DIMENSIONAL LIFT CURVE SLOPE FOR W AND H -----
30050 DEF FNLN10(X)=(LOG(X))/2.302585
30060 DEF FNAOT(M,N)=2*PI+(4.784073+1.701385*M)*N
30070 DEF FNAOR(L,M,P)=.63+.045*L+(1.45*P-2.4)*M+((.225-.15*P)*L)*M
30080 RCW=RNIN*MACW
30090 LNW=FNLN10(RCW)
30100 IF AOTW=0 THEN AOTW=FNAOT(TEPSW,TCW)
30110 AORW=FNAOR(LNW,TEPSW,XTRW)
30120 AOW=AOTW*AORW
30125 IF HT$<>"Y" THEN 30180
30130 RCH=RNIN*MACH
30140 LNH=FNLN10(RCH)
30150 AOTH=FNAOT(TEPSH,TCH)
30160 AORH=FNAOR(LNH,TEPSH,XTRH)
30170 AOH=AOTH*AORH
30180 'PANEL LIFT CURVE SLOPE FOR W AND H -----
30190 ARG=ARW
30200 LAMG=LAMW
30210 GOSUB 30310
30220 AW=AG
30230 AWD=AW*PI/180
30235 IF HT$<>"Y" THEN 30460
30240 ARG=ARH
30250 LAMG=LAMH
30260 GOSUB 30310
30270 AH=AG
30275 IF VTL$="Y" THEN AH=AH*((COS(GAMVT))^2)
30280 AHD=AH*PI/180
30290 GOTO 30390
30300 'SUB FOR LIFT CURVE SLOPE *****
30310 X=ARG:Y=LAMG
30320 A=1.822718+.539208*Y-.440856*Y^2
30330 B=-9.402938E-03-8.059647E-03*Y+5.868069E-03*Y^2
30340 C=.255117+.040266*Y-.022613*Y^2
30350 AGAR=(A+B*X)/(1+C*X)
30360 AG=AGAR*X
30370 RETURN '*****
30380 ' EFFECT OF CUT-OUT IN H. TAIL T.E. -----
30390 IF CO$<>"Y" THEN 30470
30400 XCO=BCO/(2*BH)
30410 YCO=CCO*BH/SH
30420 K1CO=.4*XCO^2-5.9*XCO/9

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30430 K2CO=.26*XCO^2-6.04*XCO/6
30440 ZCO=1+K1CO*YCO+K2CO*YCO^2
30450 AH=AH*ZCO
30455 AHD=AH*PI/180
30460 ' WING AERODYNAMIC CENTER -----
30470 X=ARW
30480 Y=LAMW
30490 K1=.0105+.3205*Y-.083*Y^2
30500 K2=.014+.25*Y
30510 Z8=.0135+.3965*Y-.167*Y^2
30520 ZO=.25-.45*Y+.2*Y^2
30530 XO=(2*Z8*(K1+8*K2)-Z8^2-16*K1*K2)/(16*K2^2)
30540 ACW=ZO+K1+K2*X-SQR((K2^2)*X*(X-2*XO)+K1^2)
30550 ' WING-BODY A.C. INCREMENT -----
30560 XK=W1W/BW
30570 YK=LAMW
30580 K1=(-1+25*XK-25*YK*XK+10*XK*YK^2)*XK/16
30590 NR=NB/CRW
30600 MR=X1W/CRW
30610 F=(-2.5+1.75*NR+6.7*MR-.4*NR*MR)/3
30620 XG=W1W/CRW
30630 G=(9.795-2.825*XG)/(6+2.5*XG)
30640 DXAC=((CRW*W1W^2*F*G*(1+.15*(H1W/W1W-1)))/(MACW*AW*SW))-K1
30650 ' WING-BODY AERO. CEN. -----
30660 ACWB=ACW-DXAC
30670 'ALPHA L ZERO AND DOWNWASH -----
30671 IF VTL$<>"Y" THEN 30680
30672 ZH=YBARV
30673 BH=Y1H*COS(GAMVT)
30680 DZH=ZH-ZW
30690 YW=LAMW
30700 TW=TAN(ALOW)
30710 TB=(ZBB-ZBN)/LB
30720 ALOB=ATN(TB)
30730 TWB=(TW*SW+TB*SB)/(SW+SB)
30740 ALOWB=ATN(TWB)
30750 ALOWBD=ALOWB*180/PI
30755 IF HT$<>"Y" THEN 31220 ' NO DOWNWASH FOR TAIL OFF
30760 XIH=2*(DZH*SIN(ALOWB)+LH*COS(ALOWB))/BW
30770 ETAH=BH/BW
30780 ZETH=2*(DZH*COS(ALOWB)-LH*SIN(ALOWB))/BW
30790 ZETB=2*(DZB*COS(ALOWB)-LH*SIN(ALOWB))/BW
30800 B=.075115-.185948*YW+.375604*YW^2
30810 C=.110606-.196401*YW+.325378*YW^2
30820 Z5=(1+B*ARW)/(1+C*ARW)
30830 K=4*(Z5-1)
30840 AIAF=(1+K*ETAH^2)*AW/ARW
30850 HPE=1+.05/XIH+.06/(XIH^2)
30860 B=.162-.393264*YW+.685792*YW^2-.294528*YW^3
30870 C=.05-.056788*YW+.237028*YW^2+.01976*YW^3
30880 HPI=(1+B*ARW)/(1+C*ARW)
30890 HP=HPE+HPI-1
30900 LA=(.21132-.392385*ARW)/(1-.995648*ARW)
30910 DHP=LA-(5.675*HPI-.875*HPI^2)/9
30920 DEDAS=2*AIAF*(HP+DHP)/PI
30930 DEDAO=(.875+ARW/16)*DEDAS
30940 FACT=DEDAO/AIAF
30950 FACT=1.2*FACT^2

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30960 DDEDA=ZETH*FACT*AIAF
30970 DEDA=DEDAO-DDEDA
30980 DZET=ZETH-ZETB
30990 EPSOL=(1.875714*DZET)/(SQRT(.013743+DZET^2))
31000 EPSOA=EPSOL-ALOWD*DEDA
31010 ' DYNAMIC PRESSURE RATIO AT TAIL -----
31020 XT=XCAH-XRTW4
31030 XQ=2*LH/BW
31040 YQ=1/ARW
31050 DBCL=(1.2*XQ*YQ)/((1-.1*XQ)*(1+3*(1+XQ)*YQ))
31060 CLW=-ALOWB*AW
31070 D=DBCL*CLW*BW/2
31080 DY=DZH
31090 Y=D+DY
31100 XTP=XT-3*CRW/4
31110 XTCR=XTP/CRW
31120 W=.55*CRW*SQRT(CDOW*XTCR)
31130 YW=ABS(Y/W)
31140 IF YW>1 THEN QR=1 ELSE 31160
31150 GOTO 31200
31160 B=SQRT(CDOW/XTCR)
31170 C=1-((1-YW^1.75)^2)
31180 QMQI=(1-B)^2
31190 QR=QMQI+C*(1-QMQI)
31200 IF VTL$<>"Y" THEN 31220
31210 ZH=Z1V
31220 ' BODY CMO -----
31230 CFAC=SW*MACW/(ALOWB*SB*LB)
31240 X=SBF*XRTW4/(SB*LB)
31250 Y=WB^2/SB
31260 A=(.015136-.0501*X)/(1+2.511456*X)
31270 B=(-.850277-.164254*X)/(1+.058497*X)
31280 C=(3.010455+3.230487*X)/(1+4.87352*X)
31290 ZM=(A+B*Y)/(1+C*Y)
31300 CMOB=-ZM/CFAC
31310 ' WING-BODY CMO -----
31315 CMOW=CMOA*ARW/(2+ARW)
31320 CMOWB=CMOW+CMOB
31330 ' ROLL DUE TO DIHEDRAL -----
31340 IF TP$="Y" THEN ETAB=2*Y1W/BW ELSE ETAB=1
31350 K=AOW/(2*PI)
31360 GAMG=ABS(GAM2-GAM1)
31370 X=ARW/K
31380 Y=LAMW
31390 B=.003325+.000871*Y-.000693*Y^2
31400 C=.175648-.13742*Y+.075899*Y^2
31410 Z1=B*X/(1+C*X)
31420 CLBF=-Z1*K*GAM2
31430 IF ETAB=1 THEN CLBD=CLBF ELSE 31450
31440 GOTO 31540
31450 N=.001063+.000398*Y-.000248*Y^2
31460 P=.35/3+.032353*Y-.031373*Y^2
31470 Z5=N*X/(1+P*X)
31480 QD=8*Z5-Z1
31490 RD=2*Z1-8*Z5
31500 ZG=(QD+RD*ETAB)*ETAB^2
31510 DG=GAM1-GAM2
31520 CLBG=-ZG*GAMG*K

```

31530 CLBD=CLBF+CLBG*SGN(DG)
31540 GAME=-CLBD/(K*Z1)
31550 ' ROLL VS CL FOR WING PLANFORM -----
31560 X=ARW
31570 Y=LAMW
31580 A=-2.460064-7.546358*Y+3.258299*Y^2
31590 B=.508118+.800278*Y-.440247*Y^2
31600 CLBCL=- (A+B*X) / (1-10*X)
31610 ' ROLL DUE TO BODY AND WING HEIGHT -----
31620 ZWD=-ZW
31630 H=4*SXS/(PI*WRTW4)
31640 HOH=ZWD/H
31650 HOB=H/BW
31660 A=.0139-.015*HOB+.02*HOB^2
31670 B=(-.004-.78*HOB+2.8*HOB^2)/30
31680 C=-.0144+.04*HOB-.16*HOB^2
31690 X=ABS(HOH)
31700 K=A+B*X+C*X^2
31710 HH=HOH-K*GAME
31720 HH29=ABS(HH)
31730 ZB5=.015*HOB+1.2*HOB^2
31740 ZB=4*ZB5*HH29*(1-HH29)
31750 WOH=WRTW4/H
31760 FA=(.08+.4025*ARW)/(1+.25*ARW)
31770 CLBH=FA*ZB*HH29*(1+WOH)/HH
31780 ALOBD=ALOB*180/PI
31790 CLBB=-.014*BVOL*ALOB
31800 ' ROLL AND YAW FOR VERTICAL TAIL -----
31805 IF BV=0 THEN GOTO 32130
31810 MV=XRTV4-XCW4
31820 H5HV=HRTV4/(HRTV4+BV)
31830 ZHHV=(ZH-Z1V)/BV
31840 BHHV=BH/BV
31850 ZWH3=ZW/HRTW4
31860 TNC2V=TNC4V-(1-LAMV)/(AREV*LAMVS)
31870 A=.51+.085*AREV-.005*AREV^2
31880 B=3.93-9.000001E-02*AREV
31890 JB=A+B*H5HV^2
31900 AV=2*PI*AREV/(2+SQR(AREV^2*(1+TNC2V^2)+4))
31905 AVD=AV*PI/180
31910 X=BHHV
31920 IF HHS="HONV" THEN 32010
31930 A=1.114+.072*X-.007*X^2
31940 B=-1.613-.097*X+8.999999E-03*X^2
31950 C=4+.04*X-.004*X^2
31960 Y=H5HV
31970 JT=A+B*Y+C*Y^2
31980 JW=1-((1-.64*ZWH3^2)*ZWH3/3)
31990 ZBRHV=.4
32000 GOTO 32070
32010 A=ZHHV^2
32020 B=-.18*X/(1+.475*X)
32030 C=.57*X/(1+.7*X)
32040 JT=1+B*A+C*A^2
32050 JW=1-((1.84-.64*ZWH3^2)*ZWH3/3)
32060 ZBRHV=.4+.1*(ZHHV+ZHHV^2)
32070 ZBR=ZBRHV*BV
32080 CYBV=-JB*JT*JW*AV*SRV

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32090 F1V=MV+.7*ZBR*TNC4V
32100 F2V=Z1V+.85*ZBR
32110 CNBV=-CYBV*F1V/BW
32120 CLBV=-CYBV*F2V/BW
32121 IF VTL$="Y" THEN GOSUB 35000 'YAW AND ROLL FOR V-TAIL
32130 ' SUM ROLLING MOMENT DUE TO SIDESLIP -----
32140 CLLB=CLBD+CLBH+CLBB+CLBV
32150 ' BODY YAWING MOMENT -----
32160 A=XC4W/LB
32170 B=LB/HB
32180 KB5=1/(2+.625*B)
32190 KB=KB5+.3*(A-.5)
32200 RTH=SQR(H25L/H75L)
32210 RW=W75L/W25L
32220 RTW=RW^(1/3)
32230 RW=ZW/HRTW4
32240 KN1=-.96*KB*RTH*RTW
32250 DKN=-.0057*(1+2*RW)
32260 KN=KN1+DKN
32270 SSB=SBP*LB/(BW*SW)
32280 CNBB=KN*SSB
32290 ' SUM YAWING MOMENT DUE TO SLIDESLIP -----
32300 CLNB=CNBV+CNBB
32310 ' ELEV. AND RUD. EFFECTIVENESS -----
32315 IF HT$<>"Y" THEN 32385
32320 IF HC$="AM" THEN LDLA=1 ELSE 32340
32330 GOTO 32365
32340 AG=ARH:X=1/AG:Y=CECH
32350 GOSUB 32450
32360 LDLA=LGLA
32365 K1H=(AH*SRH*QR)/AW
32366 K2H=K1H*(1-DEDA)
32370 CLDE=AWD*K1H*LDLA
32380 CMDE=-CLDE*(LRH+.25-ACWB)/(1+K2H)
32385 IF AREV = 0 THEN LDYB = 0:GOTO 32420
32390 AG=AREV:X=1/AG:Y=CRCV
32400 GOSUB 32450
32410 LDYB=LGLA
32420 CNDR=-LDYB*CNBV
32421 IF VTL$<>"Y" THEN 32430
32422 CMDE=CMDE*COS(GAMVT):CLDE=-CMDE*MACW/LH
32423 CNDR=-LDLA*CNBV*SIN(GAMVT)
32430 GOTO 32500
32440 ' SUB FOR E. AND R. EFF. *****
32450 A=.3875-1.5*X
32460 B=-.849844+.1875*X
32470 C=.6125+1.5*X
32480 LGLA=A*Y+SQR(B*Y^2+2*C*Y)
32490 RETURN '*****
32500 ' AILERON EFFECTIVENESS -----
32510 IF AL$<>"Y" THEN CLDA=0:GOTO 32770
32520 ' AILERON 2-DIM EFF. -----
32530 CALTP=C2W+(CTW-C2W)*(YATP-Y1W)/(Y2W-Y1W)
32540 CACR=(ALCR/C2W+ALCT/CALTP)/2
32550 X=TCW2
32560 A=(3.528-2*X)/3
32570 B=14.988095#+14.503967#*X
32580 C=-20.785714#-11.904767#*X

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32590 D=(120+125*X)/9
32600 Y=CACR
32610 A20T=A+B*Y+C*Y^2+D*Y^3
32620 X=AORW
32630 A20R=(-7.25+8.5*Y+13.25*X-8.5*X*Y)/6
32640 A20=A20T*A20R
32650 'AILERON PANEL EFF. -----
32660 ETAB=2*Y1W/BW
32670 ETAT=2*YATP/BW
32680 KA=AOW/(2*PI)
32690 AOK=ARW/KA
32700 A02R=A20/AOW
32710 ZG1=ZG
32720 ZG2=(QD+RD*ETAT)*ETAT^2
32730 CLDAP=180*A02R*KA*(ZG2-ZG1)/PI
32740 L225=.25-.35*Y+.1*Y^2
32750 KAL=(9.850001+.075*AOK)/(34.75*AOK-3)
32760 CLDA=CLDAP*(1+L225*KAL)
32770 'NEUTRAL POINT, C.G., AND CMCL -----
32775 IF HTS<>"Y" THEN 33200
32780 NP=(ACWB+K2H*(LRH+.25))/(1+K2H)
32790 K19=LRH+.25-ACWB
32800 K24=K2H*ALOWBD+K1H*(IHD-EP SOA)
32810 CMOWBH=CMOWB-((AWD*K19*K24)/(1+K2H))
32820 CLAWBH=AWD*(1+K2H)
32840 ALOWBH=ALOWBD-K1H*(IHD-EP SOA)
32850 DEOT=-CMOWBH/CMDE
32860 ICG=0
32870 PRINT
32880 PRINT "    ENTER C.G. LOCATION (MAX C.G.'S = 9)"
32890 PRINT "    `NP` FOR NEUT. PT. `E` TO EXIT"
32900 PRINT
32910 INPUT "    C.G. ",CG$
32920 IF CG$="E" THEN 33200
32930 IF CG$="NP" THEN CG(ICG)=NP ELSE 32950
32940 GOTO 32960
32950 CG(ICG)=VAL(CG$)
32960 CMCLWB(ICG)=CG(ICG)-ACWB
32970 CMCLWBH(ICG)=(CMCLWB(ICG)-K2H*(LRH+.25-CG(ICG)))/(1+K2H)
32980 DEDCL(ICG)=-CMCLWBH(ICG)/CMDE
32990 ICG=ICG+1
33000 GOTO 32910
33200 'PRINT STABILITY AND CONTROL -----
33210 LPRINT "    STABILITY AND CONTROL FOR ";AIRP$
33220 LPRINT
33230 LPRINT "    WITH AIRFOIL ";AF$
33240 LPRINT
33250 LPRINT "    *** LONGITUDINAL DERIVATIVES ARE PER DEG. "
33260 LPRINT
33270 LPRINT USING "    ALO B    ##.####";ALOB;
33280 LPRINT USING "    CLA W    ##.####";AWD
33290 LPRINT USING "    ALO W    ##.####";ALOWD;
33300 LPRINT USING "    CLA H    ##.####";AHD
33310 LPRINT USING "    ALO WB   ##.####";ALOWBD;
33320 LPRINT USING "    CLA V    ##.####";AVD
33330 LPRINT USING "    ALO WBH  ##.####";ALOWBH;
33340 LPRINT USING "    CLA WBH  ##.####";CLAWBH
33350 LPRINT

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33360 LPRINT USING "          CMO W          ##.#####";CMOW;
33370 LPRINT USING "          A.C. W          ##.#####";ACW
33380 LPRINT USING "          CMO B          ##.#####";CMOB;
33390 LPRINT USING "          D A.C. WB       ##.#####";DXAC
33400 LPRINT USING "          CMO WB          ##.#####";CMOWB;
33410 LPRINT USING "          A.C. WB          ##.#####";ACWB
33420 LPRINT USING "          CMO WBH        ##.#####";CMOWBH;
33430 LPRINT USING "          NEUT. PT.       ##.#####";NP
33440 LPRINT
33450 LPRINT USING "          EPS OA          ##.#####";EPSOA;
33460 LPRINT USING "          DCL/DE          ##.#####";CLDE
33470 LPRINT USING "          DEPS/DA         ##.#####";DEDA;
33480 LPRINT USING "          DCM/DE          ##.#####";CMDE
33490 LPRINT USING "          QH/Q           ##.#####";QR;
33500 LPRINT USING "          DEO TRIM        ##.#####";DEOT
33510 LPRINT:LPRINT
33520 LPRINT "          *** STABILITY AND CONTROL VS. C.G. "
33530 LPRINT
33540 LPRINT TAB(12);"C.G.";TAB(30);"CM/CL WB";TAB(48);"CM/CL WBH";TAB(66);"DE/DCL TRIM"
33550 FOR N=0 TO (ICG-1)
33560 LPRINT USING "          ##.#####";CG(N),CMCLWB(N),CMCLWBH(N),DEDCL(N)
33570 NEXT N
33580 LPRINT :LPRINT
33590 LPRINT "          *** LATERAL AND DIRECTIONAL DERIVATIVES ARE PER RADIAN"
33600 LPRINT
33610 LPRINT USING "          CLLB DIHED      ##.#####";CLBD;
33620 LPRINT USING "          EFF. DIHED.     ##.#####";GAME
33630 LPRINT USING "          CLLB BODY       ##.#####";CLBB
33640 LPRINT USING "          CLLB W. HT.     ##.#####";CLBH;
33650 LPRINT USING "          CLLB/CL         ##.#####";CLBCL
33660 LPRINT USING "          CLLB V.T.       ##.#####";CLBV
33670 LPRINT USING "          CLLB AIRP.     ##.#####";CLLB;
33680 LPRINT USING "          CLL/AIL.       ##.#####";CLDA
33690 LPRINT:LPRINT
33700 LPRINT USING "          CLNB V.T.       ##.#####";CNBV;
33710 LPRINT USING "          CLN/RUD.       ##.#####";CNDR
33720 LPRINT USING "          CLNB WB        ##.#####";CNBB
33730 LPRINT USING "          CLNB AIRP.    ##.#####";CLNB
33740 LPRINT CHR$(12)
33750 RETURN '-----
35000 'YAW AND ROLL MOM. COEF. FOR V-TAIL -----
35010 AV=AH*( (TAN(GAMVT))^2) 'TAN CAUSE COS IN AT LINE 30275
35015 AVD=AV*PI/180
35020 CYBV=-JB*JT*JW*AV*SRV
35030 F1V=MV+YBARH*TNC4
35040 F2V=Z1V+YBARV
35050 CNBV=-CYBV*F1V/BW
35060 CLBV=CYBV*F2V/BW
35070 RETURN '-----
40000 ' PRINT AIRPLANE DIMENSIONS -----
40010 LPRINT "          AIRPLANE DIMENSIONS FOR ";AIRP$
40020 LPRINT
40030 LPRINT "          **** WING DIMENSIONS ****"
40040 LPRINT TAB(12);"SPAN";TAB(30);"AREA";TAB(48);"ASPECT RATIO";TAB(66);"TAPER"
40050 LPRINT USING "          #####.###";BW,SW,ARW,LAMW
40060 LPRINT
40070 LPRINT TAB(12);"ROOT L.E. X";TAB(30);"ROOT CHORD";TAB(48);"TIP L.E. X";TAB(66);"TIP CHORD"
40080 LPRINT USING "          #####.###";X1W,CRW,XTPL,CTW

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40090 LPRINT
40100 IF TP$<>"Y" THEN 40140
40110 LPRINT TAB(12);"PANEL Y-STN.";TAB(30);"PANEL L.E. X";TAB(48);"PANEL CHORD"
40120 LPRINT USING "          #####.###";Y1W,X3W,C2W
40130 LPRINT
40140 LPRINT TAB(12);"MAC";TAB(30);"Y BAR";TAB(48);"X BAR 0";TAB(66);"X BAR C/4"
40150 LPRINT USING "          #####.###";MACW,YBARW,XOBRW,XC4W
40160 LPRINT
40170 LPRINT TAB(12);"WRP ABOVE FRL";TAB(30);"IN DIHED. (DEG)";TAB(48);"OUT DIHED. (DEG) ""
40180 LPRINT USING "          #####.###";ZW,GAM1,GAM2
40190 LPRINT
40200 RETURN '-----
40210 LPRINT "          **** HORIZONTAL TAIL DIMENSIONS ****"
40220 LPRINT TAB(12);"SPAN";TAB(30);"AREA";TAB(48);"ASPECT RAT.";TAB(66);"TAPER"
40230 LPRINT USING "          #####.###";BH,SH,ARH,LAMH
40240 LPRINT
40250 LPRINT TAB(12);"ROOT L.E. X";TAB(30);"ROOT CHORD";TAB(48);"TIP L.E. X";TAB(66);"TIP CHORD"
40260 LPRINT USING "          #####.###";X1H,CRH,X3H,CTH
40270 LPRINT
40280 LPRINT TAB(12);"H. T. HT.";TAB(30);"MAC H";TAB(48);"X BAR C/4";TAB(66);"H. TAIL LENGTH"
40290 LPRINT USING "          #####.###";ZH,MACH,XC4H,LH
40300 LPRINT
40310 LPRINT TAB(12);"SWEEP C/4";TAB(30);"L.H./C BAR W";TAB(48);"SH/SW";TAB(66);"H.T. VOLUME"
40320 LPRINT USING "          #####.###";SP4H,LRH,SRH,HVOL
40330 LPRINT
40340 LPRINT USING "          ELEVATOR CHORD RATIO    ##.###";CECH
40350 LPRINT
40360 RETURN '-----
40370 LPRINT "          **** VERTICAL TAIL DIMENSIONS ****"
40380 LPRINT TAB(12);"SPAN";TAB(30);"AREA";TAB(48);"EFF. A.R.";TAB(66);"TAPER"
40390 LPRINT USING "          #####.###";BV,SV,AREV,LAMV
40400 LPRINT
40410 LPRINT TAB(12);"ROOT L.E. X";TAB(30);"ROOT CHORD";TAB(48);"TIP L.E. X";TAB(66);"TIP CHORD"
40420 LPRINT USING "          #####.###";X1V,CRV,X3V,CTV
40430 LPRINT
40440 LPRINT TAB(12);"V. RT. HT.";TAB(30);"MAC V";TAB(48);"X BAR C/4";TAB(66);"V. TAIL LENGTH"
40450 LPRINT USING "          #####.###";Z1V,MACV,XC4V,LV
40460 LPRINT
40470 LPRINT TAB(12);"SWEEP C/4";TAB(30);"L.V./BW";TAB(48);"SV/SW";TAB(66);"V.T. VOL"
40480 LPRINT USING "          #####.###";SP4V,LRV,SRV,VVOL
40490 LPRINT
40500 LPRINT USING "          RUDDER CHORD RATIO    ##.###";CRCV
40510 LPRINT
40520 RETURN '-----
40530 LPRINT "          **** BODY DIMENSIONS ****"
40540 LPRINT TAB(12);"LENGTH";TAB(30);"MAX. HT.";TAB(48);"MAX. WDTN.";TAB(66);"FINNESS RATIO"
40550 LPRINT USING "          #####.###";LB,HB,WB,BLD
40560 LPRINT
40570 LPRINT TAB(12);"X-SECT. AREA";TAB(30);"PLAN AREA";TAB(48);"PROF. AREA";TAB(66);"WET. AREA"
40580 LPRINT USING "          #####.###";SXS,SB,SBP,BSWT
40590 LPRINT CHR$(12)
40600 RETURN '-----

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February 2, 1993

As promised I am providing a review of the recently published book by Dover on aircraft analysis. Like all Dover books the price is right - \$12.95. The book is: "Engineering Analysis of Flight Vehicles" by Holt Ashley first published in 1974 and recently updated. Ashley is a famous aerodynamicist who is well known for his work on flutter theory. He is the author of innumerable papers on many aspects of aircraft theory. It can be purchased from:

Dover Publications Inc.
31 East 2nd St.
Mineola, NY 11501
(516) 294-7000
Stock No- us 67213-1

The book was intended as a textbook for students with a good background in math and mechanics and who intend to go further in the study of aircraft and space vehicles. For an examination of primary forces on an airplane, Ashley uses vector notation but eventually expands it all into scalar form for ready application to problems in stability and flight path. As for aerodynamics he covers current theories on lift distribution on surfaces very thoroughly. The exposition on stability is very comprehensive and can be applied quite easily with patience. If one wishes to examine the stability of an aircraft during a maneuver the resulting expressions are in matrix form, easily computed by any of the many packaged software packages. There is addition:

Analysis of rocket flight

Discussion of supersonics

Numerical integration of equations of flight

Discussion of optimization

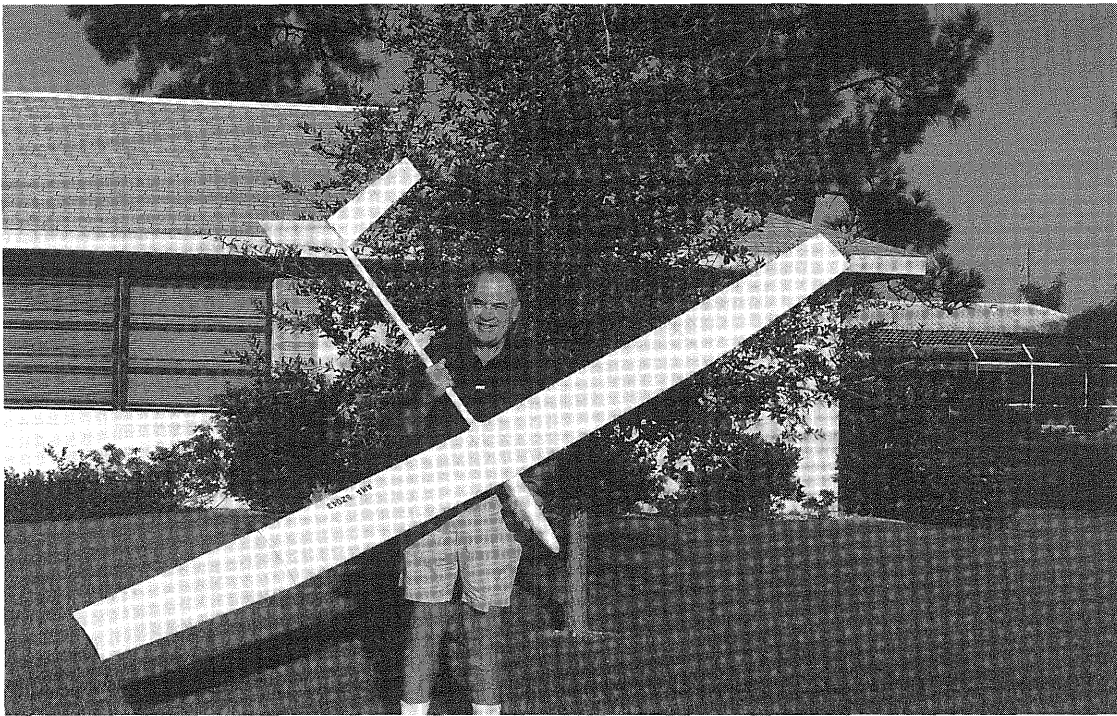
As with other publications that Ashley has produced, his writing is very lucid and direct.

As for a review of calculus and various mathematical subjects, Dover sells a variety of books that are suitable.

Finally for those that don't care to go thru Ashley's elegant exposition, I can refer them to an old volume by Perkins and Hage on Stability and Control. I don't believe that it is being published any longer but is in any university library.

Max Chernoff

(At the time of this publication, "Airplane Performance, Stability and Control" by Perkins and Hage is indeed still available - though at a very high \$95 pricetag. It can be obtained through Zenith Books 1-800-826-6600. -- Herk)



Oliver Wilson with one of his original designs that led him to develop his appreciation for Michael Selig's S-4233 airfoil.

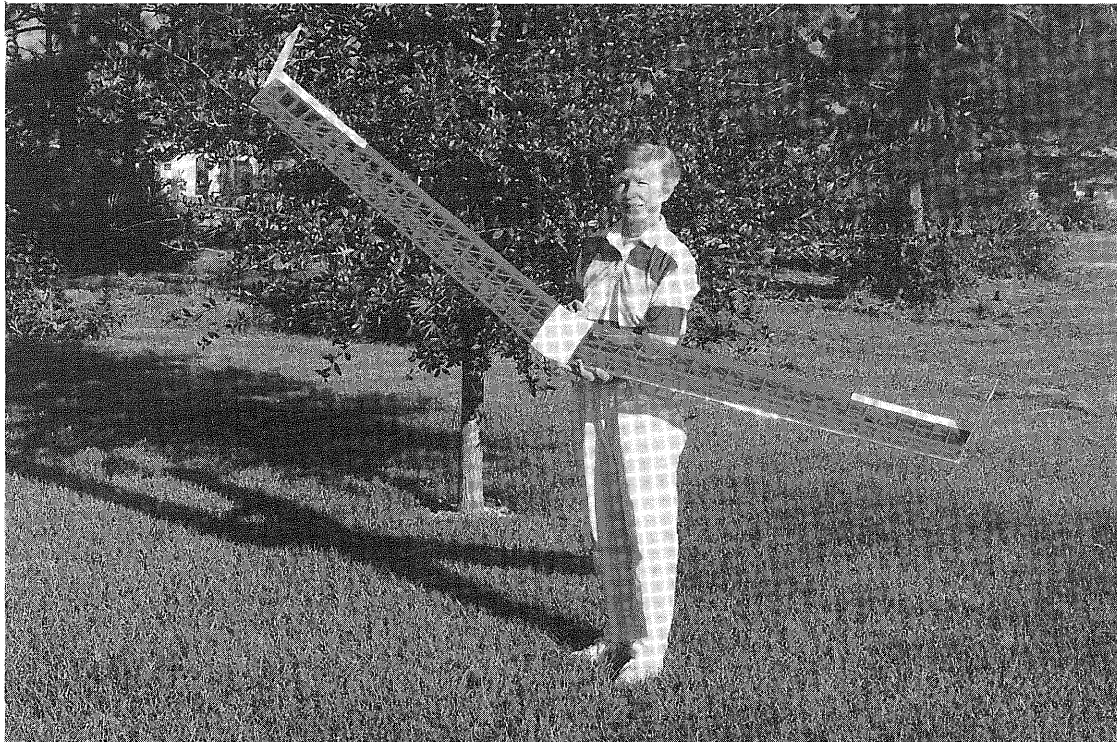


FIGURE 6.

Oliver Wilson's SELIG S-4233 equipped flying wing prototype. Based on his success with this concept, he is in the process of building a more advanced version.

THE SELIG S-4233 AIRFOIL

by Oliver Wilson

The S-4233 airfoil has been overlooked by the modeling press except for Herk Stokely in his column in FLYING MODELS. Bob Champine and some of the designers in the Tidewater area of Virginia have had good results with the S-4233. Bob used it in a stretched "Gemini" to do much of his second LSF Level V. I've built five model sailplanes with the S-4233 and all have performed above my expectations. Three of the five have been heavier than "normal" and all have had higher than "normal" aspect ratios, but none have been optimized using the David Fraser Sailplane Design program.

I've been playing with the Sailplane Design program for the last couple of years and I thought it didn't hold many surprises for me. I had been brainwashed to believe that the E-385, S-4061, S-3021, SD-7037 T30, SD-8000 and RG-15 were best for thermal soaring. Nothing I had done with the program had led me to any other conclusion. But, while attempting to optimize the design of an unlimited sailplane for thermal duration contests, I found that the S-4233 T20 could equal or exceed the performance of all the front runners, if wing span was not limited by class rules.

An attractive feature of the S-4233 T20 is its stall characteristic. As its angle of attack increases the S-4233 T20's lift coefficient increases up to a maximum at about 11 degrees. From 11 to 17 degrees the lift coefficient decreases smoothly from a peak near 1.3 to only about 1.1 where some lift is suddenly lost. In other words the S-4233 T20 can be made to mush very gracefully. This can be used to control glide path on landing approach without the complication of flaps or spoilers. On the other hand care must be taken not to fly too slowly in weak lift or altitude will be lost in mushing.

The thickness of the S-4233 has advantages and disadvantages. One disadvantage is its higher profile drag relative to the other airfoils mentioned above. This disadvantage can be partly overcome by putting a turbulator at the 20 percent chord line on the upper surface. An advantage of its thickness is its wider range of usable lift coefficients than any of its competitors, mentioned above. Another advantage is that its greater thickness permits stronger and stiffer structures than the other airfoils discussed in this paper.

The strength of a wing in bending is proportional to the square of its thickness. Table I compares the bending strength potential of the S-4233 with its thinner competitors.

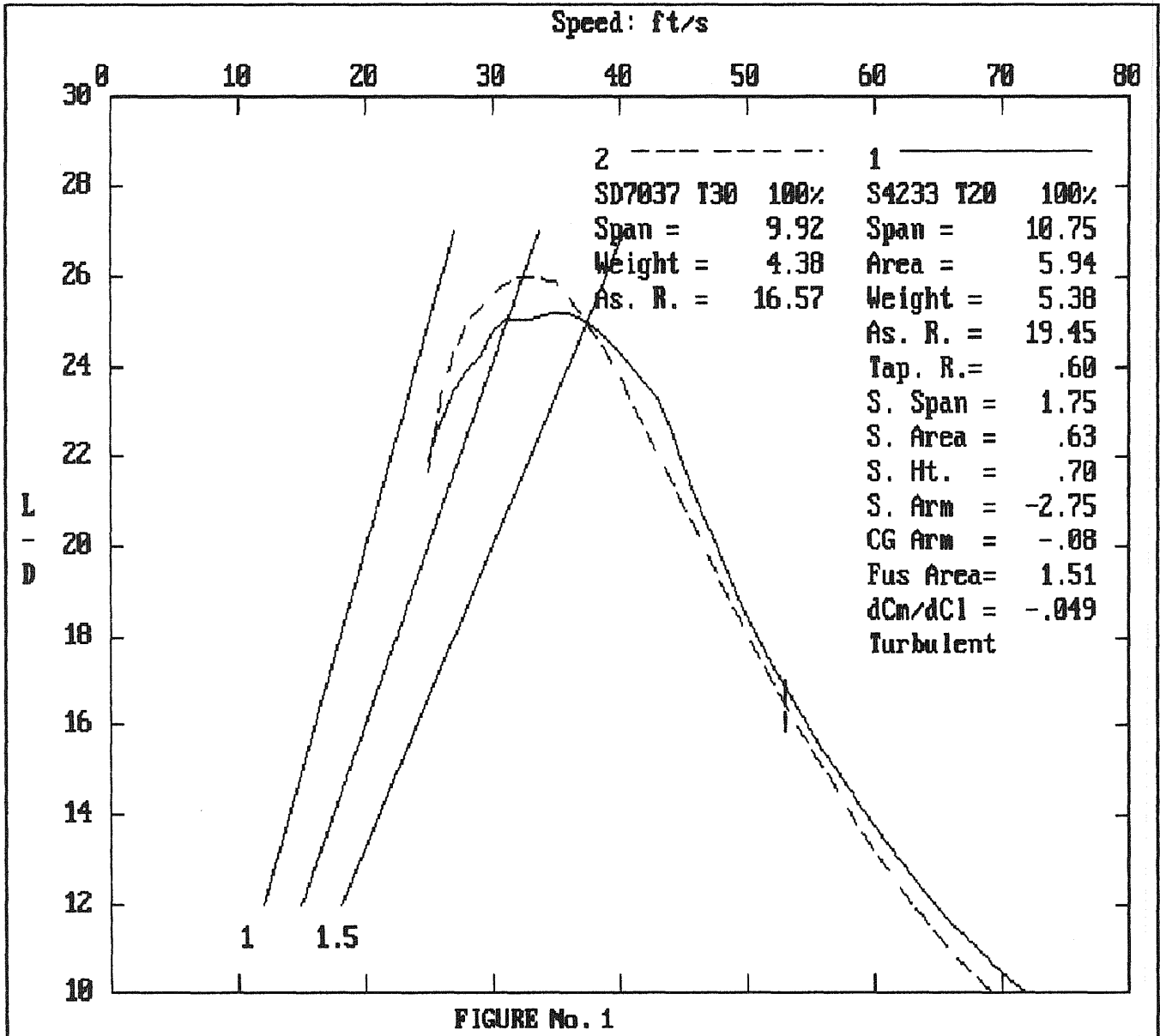
AIRFOIL	THICKNESS	THICKNESS SQRD	NORMALIZED STRENGTH
S4233	0.1364	0.0186	1.00
S4061	0.096	0.0092	0.49
S3021	0.0947	0.0090	0.48
SD7037	0.092	0.0085	0.46
E387	0.0906	0.0082	0.44
RG15	0.0892	0.0080	0.43
SD8000	0.0886	0.0079	0.42

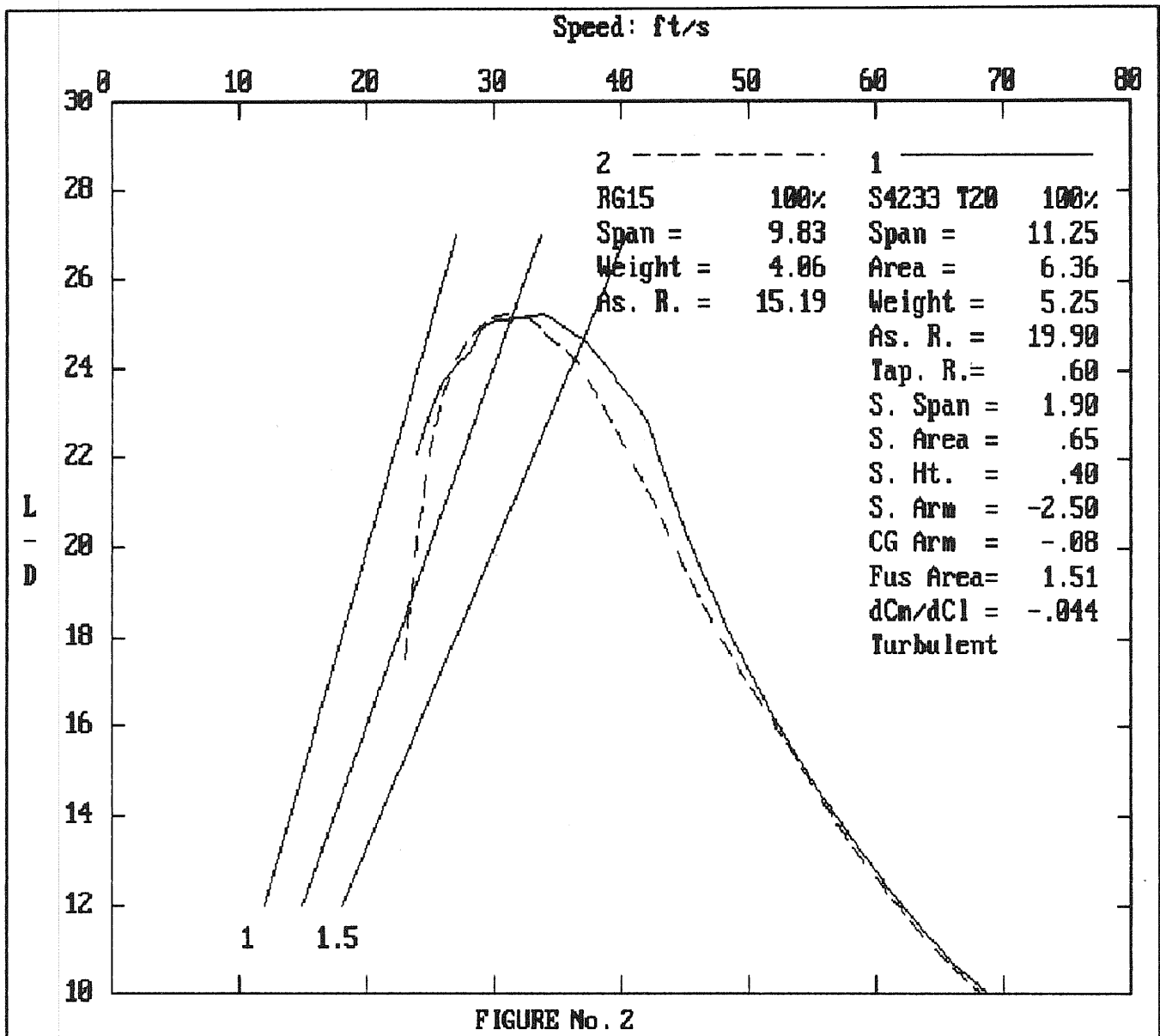
Since the bending moment of a wing at its center is proportional to the square of the span and, the S-4233 is more than twice as strong as its competitors, the span of an S-4233 wing can be more than the square root of two times the span of its competitors for the same strength. Some of this strength advantage can be allocated to aspect ratio increases and some can be allocated to load increase.

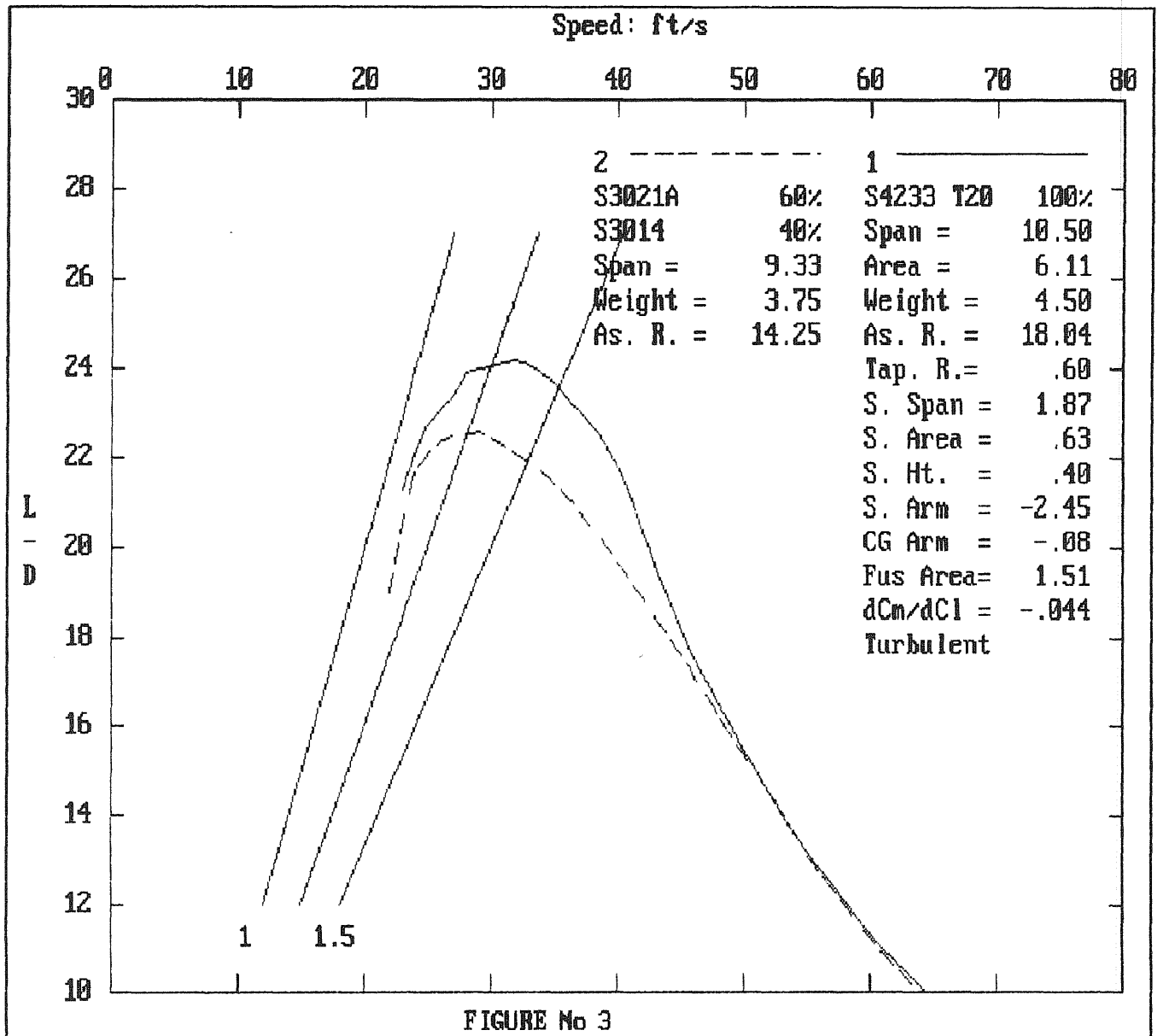
The low drag bucket of the S-4233 T20 ranges from negative lift coefficients to a lift coefficient of 1.2. Its thin competitors all have narrower low drag buckets. The higher available lift coefficient means the S-4233 T20 can carry a higher wing loading for the same stalling speed as the others. The higher aspect ratio potential of the S-4233 Allows reduction of the induced drag of the S-4233 T20 wing at its maximum lift coefficient, to a value less than the induced drag of the others at their maximum lift coefficient. in fact, there is enough induced drag reduction possible to apply some of it against the profile drag deficit of the S-4233 T20. By increasing the wing loading of the S-4233 T20 it can operate at higher lift coefficients at the same speeds so that the higher profile drag is matched with a higher lift coefficient and the disadvantage of higher profile drag is reduced throughout the speed range. Another way of looking at it is that the thin airfoils do well when designed to a minimum area loading criterion but the S-4233 T20 does better when designed to a minimum span loading criterion. Of course any loading reduction, either area or span must take into account the increase in profile drag with reductions in Reynolds number. This trade off is best handled in the Sailplane Design program.

Figures No. 1, 2, and 3 compare the performance of three popular unlimited class sailplane models with similar S-4233 T20 equipped models whose span has been stretched and weight increased. The S-4233 T20 examples have similar or better overall performance in each case, as revealed by Sailplane Design.

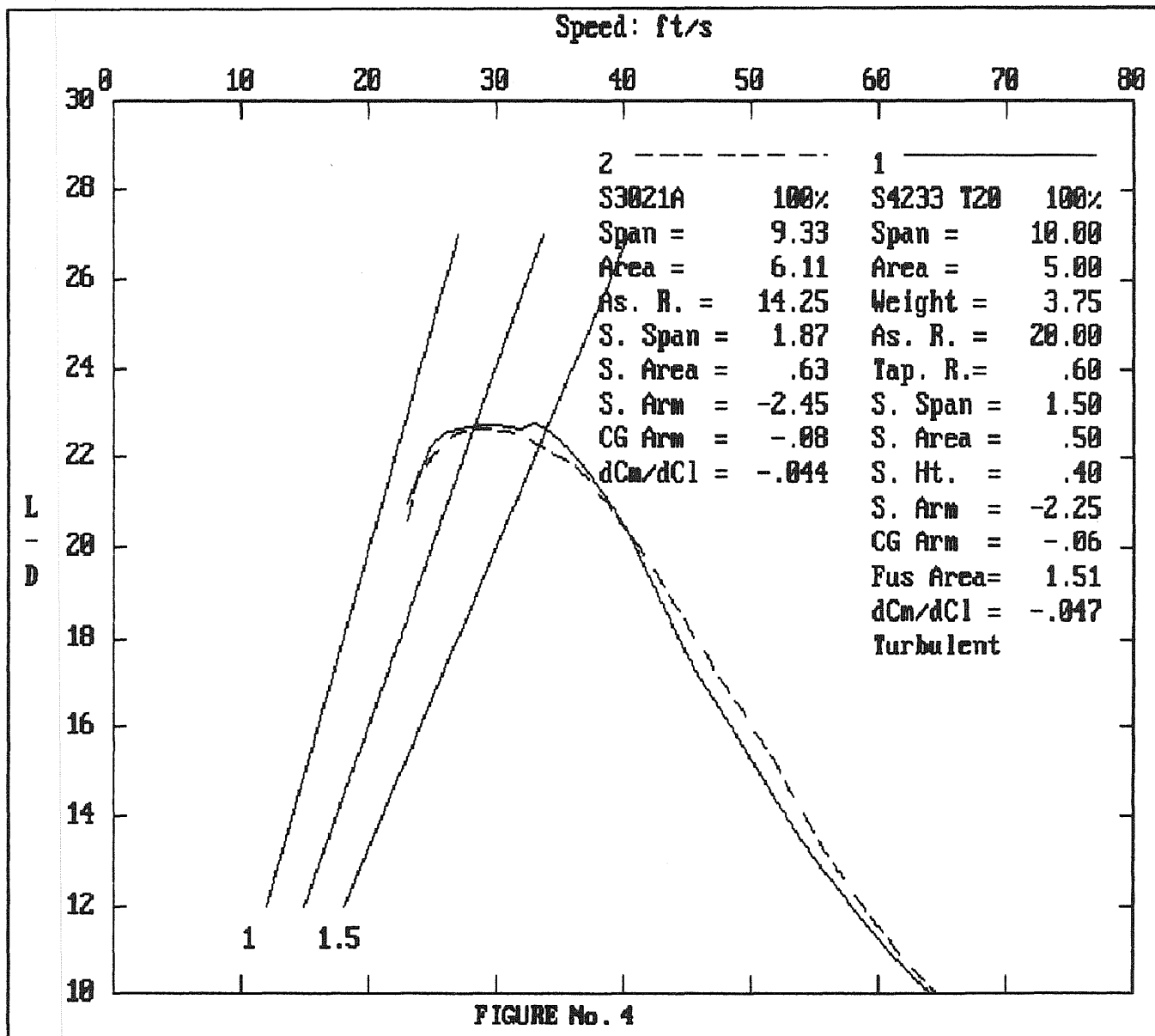
Of course the higher wing loading of the S-4233 means it can not turn as tightly for a given angle of bank but a lower sinking speed for a given forward speed means that it can be banked steeper for a given sinking speed so that in the final analysis the S-4233 T20 will thermal about as well as its competitors.



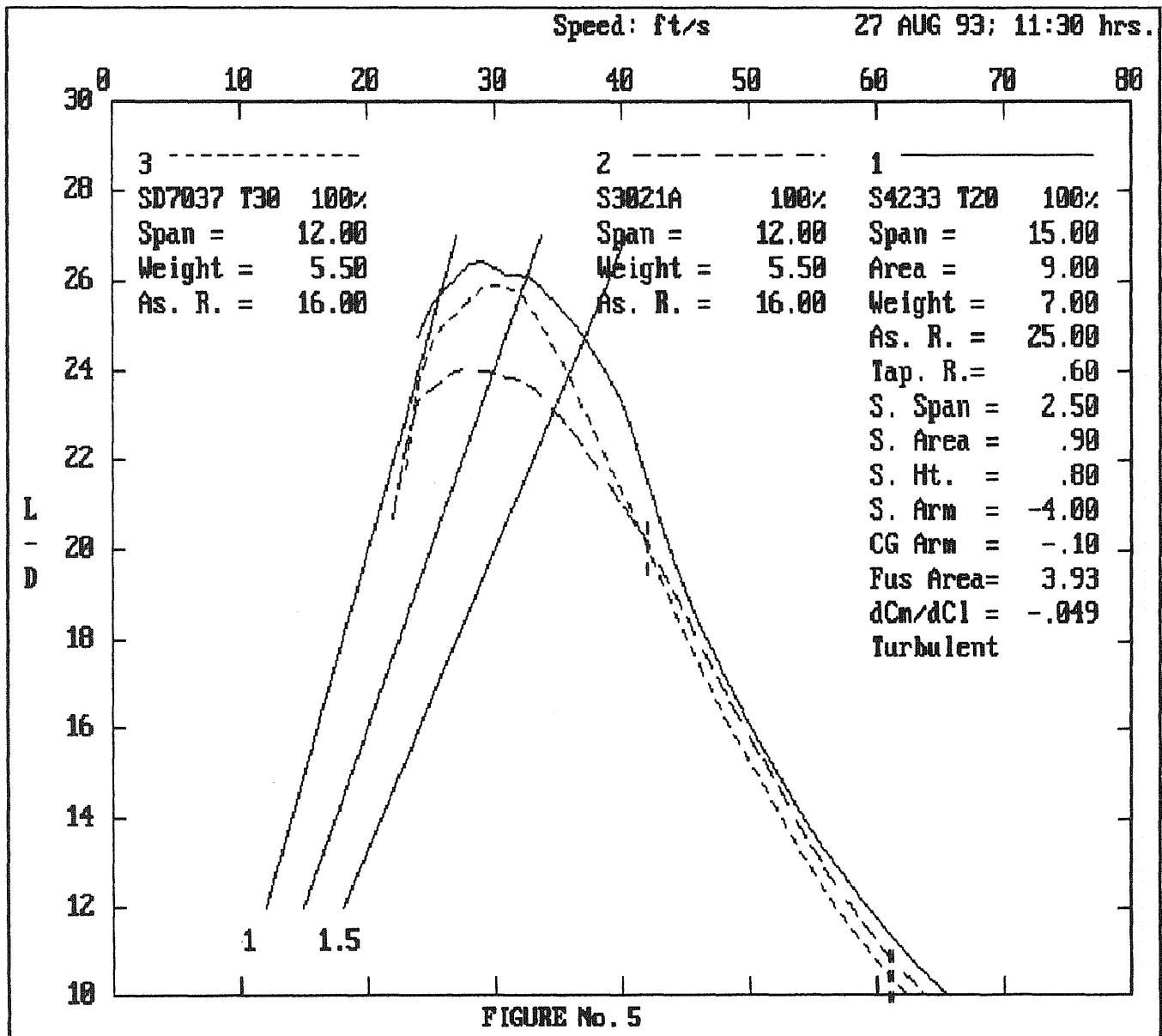




It occurred to me that the heavier S-4233 T20 equipped models might not launch as high for a given launching system. So I did another set of performance comparisons in which weight was held constant and wing area was reduced to get the requisite increase in aspect ratio. This set of comparisons was complicated by the necessity to reduce the horizontal (and vertical) tail area to correspond to the wing area reduction. This comparison is shown in Figure No. 4. Again the S-4233 performs as well as one of its thin competitors.



In Figure No. 5, I have compared a cross country sailplane configuration employing either the S3021 or the SD7037 with a similar configuration using a S-4233 T20 wing with longer span and heavier wingloading. The table clearly shows the superior performance of the S-4233. Since cross country sailplanes must operate near the limits of visibility, would such a high aspect ratio wing be sufficiently visible? I have heard that chord may be more important than span where visibility is concerned, but I have seen nothing definitive on the subject. Is there an expert on the physiology of visual perception out there who can help me with this?



Several other questions remain unanswered. The wind tunnel data for most of these airfoils does not include operation with flaps. While the benefits of flaps on the thin airfoils seems well established through extensive usage, the benefit of flaps on the S-4233 T20 is less certain and quantitative comparisons of these airfoils with flaps seems unlikely for the time being. My experience with flaps on two of the S-4233 models I have designed and built indicates that flaps are effective for glide path control but their effectiveness during launch, thermalling and high speed dashes between thermals is inconclusive.

Another possible application for the S-4233 is in swept-back flying wings. Such a configuration requires a bell shaped lift distribution to achieve adequate longitudinal stability. It also places great demands on the bending and torsional stiffness of the wing structure. The thickness of the S-4233 not only eases the design for stiffness but also provides the depth for mounting radio equipment on shorter chord sections than its thinner cousins. The aspect ratio of a swept-back flying wing must be much higher than its counterpart in conventional configuration to achieve comparable low speed performance because of the induced drag penalty of the bell shaped lift distribution. FIGURE No. 6 shows a flying wing I designed around the S-4233. It had a span of 100 inches, an area of 900 square inches and a weight of 3 pounds. My impression was that it had a performance envelope similar to the Sagitta 900. The construction was open bay with spruce sparcaps, and extensive diagonal bracing between the ribs. Even though the sparcaps were 3/8 by 1/2 inches top and bottom the wing flexed enough on a pedal-to-the-metal launches that the up-elevator effect of the flex would cause a high speed stall and pin-wheel maneuver. On more reasonable launches it tracked straight and true to about 80 or 90 percent of normal launch altitude. I am in the process of building a larger version in which the aspect ratio has been increased from 11 to 14 and the spruce replaced with carbon fiber sparcaps and diagonals.

In the case of a maximum wing span specification as in Class A, B, or C sailplanes, the thin airfoils above may be superior to the S-4233. However, for scale models with aspect ratios in the range of 18 to 36, the S-4233 is clearly the best choice from both a strength and performance point of view. For unlimited class sailplanes and for cross country the S-4233 T20 can give its thinner cousins a run for their money.

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Wednesday, April 14, 1993 — Sunday, May 9, 1993

AIRFOILS FOR AEROBATIC SAILPLANE WINGS

INTRODUCTION

Until recently there was little published in the U.S. with regard to sailplanes designed primarily for precision aerobatics [Raskin 1992b]. Available sailplane analysis methods of the past two decades, both written and programmed [for example: Hohnesee 1990; Stokely 1982 through 1990; Lister 1974, Lister 1980], though excellent in what they do cover, tend to ignore the needs of designers of this class of models. A few designed-for-aerobatics kits from Europe, such as the Phase 6, have had symmetrical airfoils, but U.S. aerobatic kits, excepting the author's Anabat series, do not have the airfoils that precision aerobatics demands.

R/C sailplane aerobatics are becoming increasingly popular as pilots discover the excitement of expanding the flight envelope of their planes and sharpening their piloting skills. As even the staid AMA—for once ahead of the crowd—points out [AMA 1992], it is an event that can be flown at either thermal or slope sites, and has a potentially large audience. From a P/R point of view, aerobatics is much more dramatic to watch than, say, a thermal competition. Up to this year, there has only been a single AMA-sanctioned precision sailplane competition held annually (by the San Francisco Vultures), but a number of such contests are being scheduled by various clubs in 1993 and national-level competition may not be far off.

WHY SYMMETRY?

As soon as you decide to design a plane that will respond the same upright and inverted, you need a wing airfoil that has the same characteristics either way. As designers of full-size powered aerobatic planes and powered models have known for years, the requirement is fulfilled by an airfoil where the curve on the top and bottom are congruent. Turn one upside down, and it looks just the same as it did upright.

In a plane with no decalage (both the wing and the stabilizer have the same angle of incidence, preferably zero), the same amount of control input (if in opposite directions) is required to do an inside and an outside loop, and these loops will be of equal radii. For such a plane to be stable in upright level flight it requires some up elevator (and/or positive camber). Sustained inverted flight requires a little bit of down elevator (and/or negative camber). With the elevator and flaps or camber changing devices (not necessarily the stick!) neutral, a properly set up aerobatic plane will go into a perfectly vertical dive.

The question has been raised whether an appropriately recurved meanline airfoil would also

serve for aerobatics [Stokely 1993] but the present author believes that the best path to pursue in the quest for high performance lies in symmetrical airfoils with flaps and, perhaps, camber-changing leading edges as well.

Another advantage of symmetrical airfoils is that you can get away with making two left wing cores.

CAMBER

All non-symmetrical airfoils have some camber, the amount of which is expressed as a percentage of the chord. Some, like the SD7003, have very little (in this case, less than 2%). Others, like the NACA6409, much used in free flight models, has a lot (6%). More camber means a higher maximum coefficient of lift (C_l), but it also means more drag at lower coefficients of lift. More camber also means that the wing generates a greater torsional force (C_{mo}), and requires a larger stabilizer. In general, the greater the camber, the more difficult it is to fly the airfoil inverted. Conversely, a symmetrical wing has no camber at all, does not have a high maximum coefficient of lift, but has little drag at low coefficients of lift. It flies inverted as well as it flies upright. Since $C_{mo} = 0$, no external stabilizer at all is required, which makes such airfoils popular for flying wings. The flying wing configuration, however, is usually not preferred for precision aerobatics. In particular, autorotational maneuvers (e.g., snap rolls and true spins) seem more easily accomplished with conventional aircraft configurations.

The secret of successful application of simple symmetrical airfoils is to use them in planes designed to fly at low coefficients of lift. Such planes are very light for their wing area or very fast for their size. Many famous racing planes (such as the Thompson Trophy-winning Turner Special) used symmetrical airfoils for their low drag properties even though there was no intention of flying them inverted [Schmid and Weaver 1991]. Many famous aerobatic planes (back to the 1930's) [Carson 1986] used symmetrical airfoils for the quality of inverted flight they imparted. My Anabat series of planes all use symmetrical airfoils for their aerobatic properties. Fears that they would not behave well in light lift, a reason often cited for not using symmetrical airfoils in sailplanes, turned out to be unfounded. At a given C_d , the C_l of most symmetrical airfoils will be about 75% to 80% of that of a typical asymmetrical airfoil, hence a 20% increase in area or decrease in weight will yield (very roughly speaking) comparable flying qualities. Most of the time the loss in L/D is unimportant since the task the plane is flying does not require extreme performance in that direction. In any case, the penalty for using symmetrical airfoils is not as great as often assumed.

AVAILABLE AIRFOILS

Full-size glider designers have Wortman's symmetrical, flapped sections such as the FX 71-L-150/25, as used on the aerobatic Celstar GA-1 from South Africa [Celair 1989]. The German Mü-28 aerobatic sailplane, made by Akaflieg München, also uses a Wortman symmetrical section. Model glider designers are not so fortunate. Aside from the author's own WE series, he has not been able to find any symmetrical sections specifically created and tested as model glider wings. Into this vacuum have fallen the classic NACA 00xx series (typically the NACA 0006, 0009, and

0012) designed for full-size aircraft and the newer SD8020 [Selig et. al. 1989], designed for use in model tail surfaces, especially all-flying stabilizers and fins. All will fly sailplanes. The NACA 64-series symmetrical airfoils are not suitable for model sailplane use [Selig et. al. 1989].

The SD8020 has been used in some quite successful models, including ones built by the author. However the WE3008 appears, in practice, to be even better for some aerobatic aircraft. The approach to designing this airfoil has little theoretical justification behind it and came from an observation from full-size aircraft designer Martin Hollmann [Hollmann 1989] that the Extra 230-260-300 series of aircraft as well as some of the Mudry CAP series used an airfoil that was a simple elliptical curve faired to two straight lines.

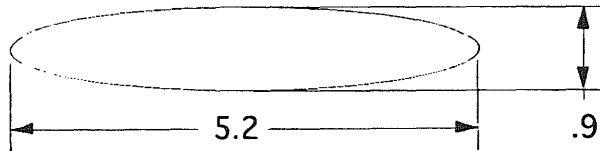
To construct a WE series airfoil, the designer has only two parameters to adjust, the maximum thickness and the location of that maximum, both of which are conventionally represented as a percentage of chord. In the WE 3008 the “30” means that the maximum thickness occurs at 30% of the chord, and the “08” means that the maximum thickness is 8% of the chord. U-control designers have used such airfoils for many years, if much thicker and with high points more forward (eg. WE2022). These are well suited to U-control where power is not lacking and drag no penalty, indeed a help in keeping the speed of the model from getting out of hand when descending.

I wish I could say that years of computer simulations and advanced thinking led to choosing airfoil, but in fact I decided to try one simply because it was easy to lay out, and with its large flat area, easy to build on a flat board and align the ailerons to. A flying testbed was built, and I learned that the WE3312 did not work nearly as well as my first wing, which used the SD8020. I attribute the problems (e.g. inability to deal with high winds, poor vertical performance) of the WE3312 to its excessive thickness. The third try, a WE3008, performed noticeably better than either. In each case the size of the wing (36” span and 8” chord) and all other parameters of the model were kept fixed. One such experiment does not prove much, since many other factors including subjectivity, weather, and possible errors in layout, construction, or mounting of the airfoil may have as much effect as any true aerodynamic factors. However, even if the WE3008 were no better than the SD8020, its ease of layout and convenience in building and trimming would make it my airfoil of choice.

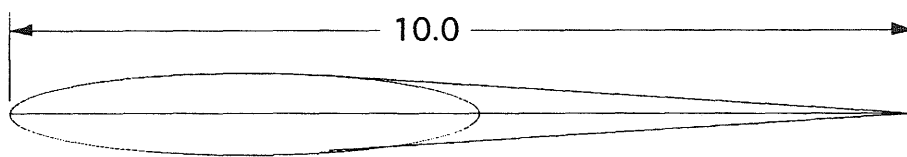
CONSTRUCTING A WE¹ SERIES AIRFOIL

Say that you want a 9% thick WE-series with a 10 inch chord and the point of maximum thickness at 26% of the chord. Create an ellipse whose minor *diameter* is the desired thickness, namely 9 percent of 10 inches or 0.9” and whose major *radius* is the distance to the point of maximum thickness, in this case 26 percent of 10 inches or 2.6 inches. The major diameter of the ellipse is therefore twice this or 5.2 inches. Such ellipses are trivial to construct with a CAD program.

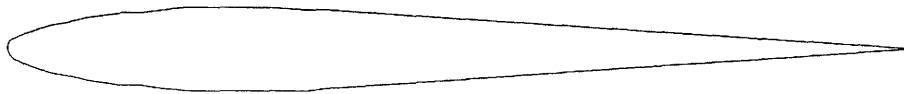
¹The “WE” designation stands for at least one of the following: “weeeee!” the sound you make when you see how these foils fly; for the initials of Walter Extra; or for “Wedged Ellipse.”



Construct the center line to the desired chord length and then two lines from its end so that they are tangent to the ellipse. This gives the basic outline.



Now just erase the part of the ellipse you don't need, and there's your foil:



In general: you need the chord, C ; the thickness ratio t ; and the point of maximum thickness q . Draw an ellipse with minor diameter $C*t$ and major diameter $(C*q)/2$. Construct a line of length C along the major diameter from one end of the ellipse. From the other end of the line construct two tangents to the ellipse on opposite sides of the line. That's it.

AILERON SIZE AND PIVOTING WINGS

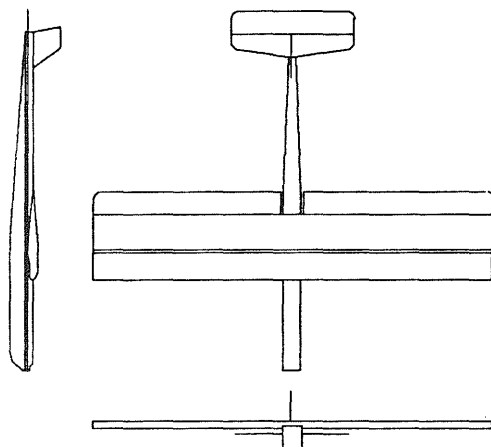
When I first started building aerobatic sailplanes, I tended to copy aerobatic power planes. I soon learned that the small ailerons that worked so well with power yielded roll rates that were insufficient for precision aerobatics at the slope. A typical example was a scale Mustang kit that was quite aerobatic with its scale-size ailerons under power. The same plane, at the slope (or when gliding over the airfield), rolled with painful slothfulness. I then attached the flaps to the ailerons to give the plane full-span ailerons, which made the roll rate satisfactory.

Just as full-size aerobatic gliders have gone to full-span ailerons that cover 25% of the chord of the wing, my designs have ailerons that range from 25% to 33% of the chord. With large ailerons, most rolls are made with relatively small aileron deflections, giving a better lift to drag ratio in the maneuver than would a small aileron with large deflections. As a control surface is increasingly deflected, its drag rises faster than its lift. However, this reasoning does not extend to the use of pivoting wings (100% aileron) because such a wing is not a cambered surface and does not have as good a lift-to-drag ratio as a conventional wing-and-aileron. At large deflections pivoting wings are much easier to stall than conventional ailerons: after about 10° of deflection they

stop increasing the lift (roll force) and only increase drag. Incidentally, this indicates that pivoting wings used as ailerons should never move more than this amount. Better than either would be a pivoting wing with an aileron that moves through a larger angle than the wing (some Piper aircraft have a stabilizer that operates exactly this way). The added complexity of this mechanism and the satisfactory response of conventional ailerons means that we are likely to see few, if any, compound moving wings.

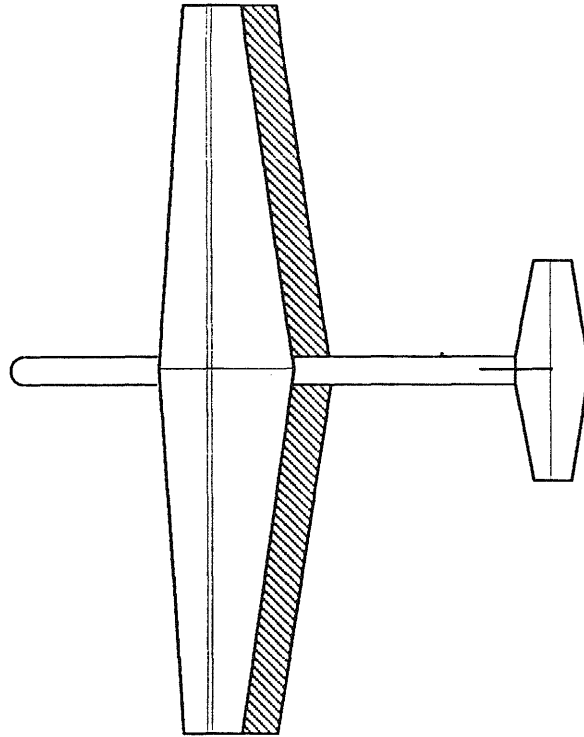
Roll rates must be high in order to make point rolls crisp, to be able to complete vertical rolls upward before the model runs out of kinetic energy, and to be able to complete vertical downward rolls before running out of altitude. High roll rates (once you've learned to fly them) are also great when landing in sloppy air. It is well known, but bears repeating, that all aerobic models must have their wing/aileron gaps sealed [Raskin 1992b]. Such sealing is assumed in this discussion.

The Anabat 2, which has won many formal and informal aerobic contests, has 8" chord and 2" wide ailerons. At maximum deflections, it rolls more like a propeller than an airplane. When the ailerons are neutralized the plane stops rolling as if it had brakes. Point rolls are very impressive and the appearance of precision is emphasized.



The Anabat 2 Kit

The rectangular platform is very good for training as it has extraordinarily gentle stall characteristics and it is easy to recover from mistakes without much loss of altitude. Higher performance Anabats have tapered wings.



The Anabat 34, under test in 1993 slope season, possibly a kit in '94
It has tapered wings and a higher aspect ratio. Root WE2510, Tip WE2506.

With some wing/aileron combinations, the aileron is “blanked” by the wing so that it has no effect until it achieves a significant amount of deflection. This is very undesirable as it gives the pilot a deadband where small motions of the stick do not affect the roll at all, and where rolling starts abruptly once the stick is moved past a certain point. This can usually be fixed by making the leading edge of the aileron a few percent thicker than the trailing edge of the wing where the aileron attaches. This extra thickness seems to cause the air flow to reattach and cling to the aileron. The WE-series of airfoils has not exhibited this problem, and the Anabats respond to small aileron deflections with low, predictable roll rates.

WIND TUNNEL TESTS DESIRED

It would be desirable that a series of these foils, with thickness from, say 6% to 15% in 3% increments, and positions of maximum thickness from 15% to 40% in 5% increments, can be tested. I had wanted to do this with the Princeton tests [Selig et. al. 1989], but I learned about the tests very late and after I had made my first test section for them, we sold our house and I had to pack up my shop. I have always regretted not being able to supply the 24 airfoils that I had planned for the tests. The tests were over before I had a chance to set up my new shop.

It would be interesting to get the airfoil polars from a low-speed airfoil computer program.

COUPLED FLAPS

An airfoil with no camber is quite efficient at very low coefficients of lift, but we are not always flying nearly straight up or down or at top speed. In some flight regimes you do need higher coefficients of lift, where a symmetrical airfoil is inefficient. For turns and inside loops a positively cambered airfoil would give us a better lift-to-drag ratio than an uncambered symmetrical one. In outside loops and negative-g turns, we would get better performance from a wing that has negative camber.

We can have it all if we use flaps. Sharing the idea with control-line fliers, fun-flyers, and full-scale practice, the flaps can be rigged to move up when the elevator goes down and vice versa. When you do this the sailplane takes on almost magic properties. The wing is automatically cambered in the right direction at all times so long as you have no flap when the elevator is dead straight (again, remember that these designs have no decalage, that is, they are set up "zero-zero"). With a bit of up elevator in normal flight you have a cambered airfoil, and the camber decreases as you push on the stick. In inverted flight you have pushed ("down") elevator and you still have a properly cambered airfoil.

With computer radios it is convenient to use full-span flaperons: ailerons that can move up and down together as flaps. There is some aerodynamic advantage to this: separate ailerons and flaps can generate extra drag where the flaps end and the ailerons begin. A further refinement would be to have a leading edge that moves down when the flaps do and vice versa. The idea is by no means a new one, but the mechanical complexity may not be worth it in terms of improved flight performance.

I built my first aerobatic glider with coupled flaperons (the "Speedemon") before 1980, and I have been hooked on them ever since. The variable camber makes a small, light model equipped with them nearly as agile as a bird. With coupled flaps loops are tighter, turns faster, landing is easier, and the plane is all the more a joy to fly. My 12 oz., 36" span four-channel Anabat can fly in winds that were measured at from 3.5 to 45 mph. True, at the low end it was just clinging to the edge of the cliff, not gaining more than five feet of altitude, but it was flying. Turning off the coupled flaps raised the minimum wind speed to about 5 mph. With a 45mph gale and using the flaperons, the model took a while to get away from the edge of the cliff, but it did it smoothly and the aerobatics in the powerful lift were spectacular. Without the flaperons, the plane would still handle the winds, but it was much more difficult to keep it from ballooning up and over my head.

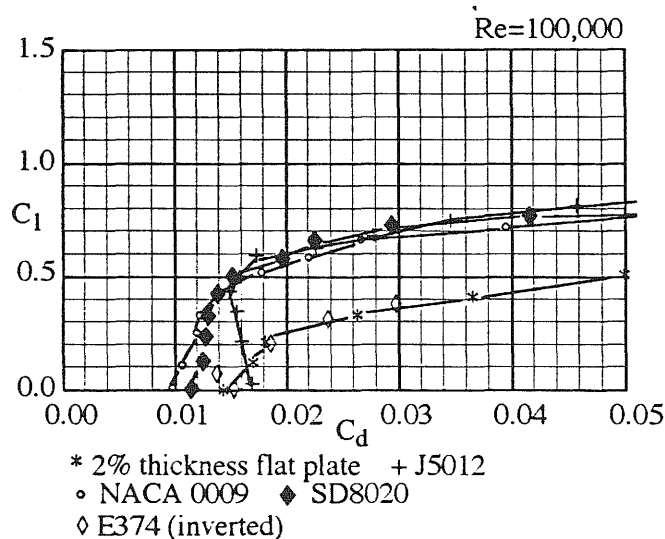
[Stokely 1993] suggests that greater efficiency may be obtained by having separate ailerons and flaps and deflecting the flaps less than the ailerons, thus achieving washout. I have not tried this and wonder if the losses at the flap-aileron juncture (a vortex will form there) will undo some of the efficiency the washout affords. In any case, it is a clever way of achieving washout that remains washout when inverted! It would be easy to implement with a computer radio and a four-servo wing.

CHOOSING A SYMMETRICAL AIRFOIL FROM PUBLISHED DATA

There are two important caveats in reading polars, well known to designers:

- The tests must have been done at the same Reynolds number at which your model will fly
 - You cannot always directly compare tests done in different wind tunnels²
- These points are very well made in [Selig et. al. 1989] and I will not discuss the interpretation of airfoil data further, but refer the reader to other sources if you are not familiar with reading these charts [Simons 1987].

Note that these polars, unlike most, do not go down below 0 for the coefficient of lift. That is because the curves for symmetrical airfoils are themselves symmetrical, the zero-lift angle of incidence is always exactly zero degrees, and the chart below the origin would be redundant.



Here, the polars for four of the symmetrical airfoils and the characteristics of the Eppler 374, flying inverted, from Selig et. al. [1989] are plotted together at $Re=100,000$. It is clear that the flat plate is decidedly inferior. At any amount of lift, it has more drag than any of the others, even though they are all much thicker. If any demonstration of the effectiveness of streamlined shapes is needed, this should do. At a coefficient of lift of 0.3 the coefficient of drag (C_d) of the NACA 0009 or SD8020 is about 0.012; the flat plate as twice the drag with a coefficient of drag of 0.024, though it is about one fifth the thickness of the other two! The flat plate, of 12" chord and 1/4" thickness, had its leading edge rounded and its trailing edge tapered over the last three inches to 1/32". It would have been worse if it had had a rounded rather than a tapered trailing edge and much worse if the edges had been left square, as careless modelers often do.

The E374, used on a many current "aerobatic" designs, is nearly as bad as a flat plate when it is flying inverted! It is often chosen for aerobatic models, I believe, since it has a relatively small camber (2.24%) compared to many other popular sailplane airfoils and thus looks at first blush attractive for inverted flight. The actual data—typical of many conventional airfoils—shows why it

²Polars for the NACA 0009 in [Lennon 1986] differ somewhat from those in [Selig 1989]. Take these things with a grain of salt, and expect that some calculations can be off by a factor of up to two.

is difficult to get some models to maintain altitude in inverted slope flight. Selig et. al. do not take the data for this or other airfoils into larger negative C_l since they were not interested in inverted performance. I hope that future tests take aerobatic use of airfoils into greater consideration.

The J5012, the symmetrical outline of the old (pre WWII) Göttingen airfoils, shows the increasing drag as it approaches a coefficient of lift of zero that is characteristic of symmetrical airfoils designed to operate at Re higher than what is typical of models. On the basis of these curves, there is little to choose between the SD8020 and the NACA 0009. What one wants is the most lift for the least drag, and the marginally higher coefficients of lift of the SD8020 can be attributed to the fact that it is thicker (about 10%) than the NACA 0009 (9%). An NACA 0010 would probably be indistinguishable from the SD8020 on such a chart. As [Selig, et. al. 1989] points out, the SD8020 has some advantages as an all-flying stabilizer, but as a model aircraft wing these two airfoils would probably behave nearly identically.

Unfortunately, curves for the WE series are not yet available and the conservative modeler who does not trust the enthusiastic accounts of Anabat fliers might choose the SD8020 or NACA 0009 and get essentially the same performance at only a small additional cost in time and effort.

DESIGNING THE IDEAL AEROBATIC AIRFOIL

Obviously, the ideal airfoil for sailplane aerobatics would have a good lift-to-drag ratio over all applicable Reynolds numbers. The absolute drag would be low, the maximum coefficient of lift high. I suspect that it is impossible to do much better than the airfoils already discussed, but I do not know this for a fact and I hope that our better airfoil designers take this as a challenge. None of the airfoils in [Selig et al. 1989] get to a coefficient of drag below 0.07 at $C_l = 0$ (at an Rn of 300,000), and the NACA 0009 is as good as any (actually better than most) in this regard. Similarly, it is difficult for any symmetrical airfoil of thickness ratios in the 10% range to get a coefficient of lift over 0.8. For snap rolls and similar autorotational maneuvers, a clean stall would be desirable, with the lift falling off abruptly once the wing exceeds a certain angle of attack. This might be provided by designing an airfoil with a sharper leading edge than is typical. An abrupt stall break can be achieved with any airfoil by decreasing the chord of the wing at the tip (a lower tip/root chord ratio). Fixed washin or washout cannot be used in aerobatic planes since any benefit is reversed when inverted.

Stokely [1993] suggests that, just possibly, an asymmetrical foil "with the max camber fairly far aft, and lots of Phillips entry...becomes a reflexed airfoil inverted, and some perform very well inverted with almost no change of elevator position." I suspect that either upright or inverted performance would have to suffer with such a foil, but there are an infinite number of possible airfoils and I certainly cannot claim that there might not be an asymmetrical one out there that is better for aerobatics. But I have my doubts: only analysis and testing will tell.

It is my guess that little can be done to lower the minimum C_d and simultaneously raise the maximum C_l of symmetrical foils beyond what has already been achieved, though I hope that someone will prove me wrong. I have no proof of this, my guess reached by studying polars of many symmetrical foils looking for better ones and not seeing anything inspiring. If I am right, future aerobatic airfoil designers should concentrate on optimizing L/D and maximum C_l with the

use of flaps, assuring smooth change of lift with increasing aileron deflection (especially at small deflections so that there is no deadband), and on achieving the desired stall characteristics.

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ANOTHER LOOK AT WIND TUNNEL RESULTS

By Martin Simons

In *Soartech 9* a paper which I presented at the Royal Aeronautical Society conference on low speed aerodynamics in 1986, was reprinted. The paper demonstrated a method of using wind tunnel test results in order to calculate the performance of a sailplane wing. Some results were presented which referred especially to the F3B type of contest sailplane. This article is intended to bring the commentary up to date.

During 1990 and 91, in the magazine *RC Soaring Digest* published in Wylie, Texas, by Judy & Jerry Slates, I applied the same methods of calculation to the F3J type of thermal soaring sailplane. Although the computer program used was written about ten years ago, it remains valid, with some adjustments to suit it to more sophisticated machinery.

The basic principle is that in sailplane design the wing is by far the most important component. Fuselages, tail units, and other parts of the aircraft are much less significant. If the wing is good, assuming the rest of the model is reasonably in proportion the sailplane will perform well.

Since the R.Ae.Soc. paper was written, a great deal more wind tunnel data has become available. The admirable research results of Michael Selig, John Donovan and the late David Fraser at Princeton University, were published in *Soartech 8* in 1989. This monumental work contains an enormous amount of invaluable data. It has become indispensable for the serious model sailplane designer and is of significance for anyone concerned with remotely piloted small aircraft. It will be a long time before this work is equalled or surpassed.

Other teams of wind tunnel engineers, at Stuttgart, Delft, Brunswick, Cranfield and Notre Dame Universities and elsewhere have contributed and continue to do so.

The difficulty remains that when similar models are tested in different wind tunnels, they produce somewhat different results. Experimental error is unavoidable. It is instructive to compare the figures from one research laboratory with those from another for the same nominal wing profile. Quite large differences commonly appear, especially at the low Re numbers which are of interest to us.

One advantage of the Princeton work is that the sections were all tested under the same conditions. Hence the *Soartech 8* charts are consistent one with the other.

In addition, each test model was carefully measured and all departures from the ordinates were meticulously noted. For example, the model of the well known Eppler 193 section tested at Princeton, was discovered to be closer to the Eppler 205 than to its own nominal ordinates. How easy it is for such an error in construction to develop becomes apparent if tracings of these two sections are laid one over the other. They are almost the same, within the thickness of a normal line on the drawing, except for a slight variation at the trailing edge where warping can easily occur. On a wing chord of approximately 150 mm, the difference at the extreme trailing edge is about 3 mm. Many model wings in service are less accurate than that at the trailing edge.

The average model builder does not achieve a high standard of airfoil accuracy. Even those who build model wings professionally from very carefully made moulds, in the manner of full scale sailplane construction, do not in fact achieve perfect form. Nor, for that matter, do the full scale sailplane manufacturers. In any case, after leaving the moulds, the wings often tend to change slightly as the material of their construction shrinks or shifts with use.

Over and above all this, models in flight pick up dust and dirt, just as full scale

wings do. The surface becomes contaminated and this has effects on the airflow.

For all these reasons, experimental error, inaccuracies in model construction, and contamination, it is probably wrong to place too much emphasis on the fine details of the wing profile. Even if one profile does seem to have a slight advantage in the laboratory test, we have to treat this with a good deal of scepticism when it comes to flying.

Having said all this, it is worth running some data through the computer to see what difference the choice of section might make. The main criteria of camber and thickness still apply. It would clearly be a mistake to use a strongly cambered thick wing profile on a model intended for speed flying. Experience indicates that the successful F3B sailplane will have a thin wing, about 9% chord, and a small camber, about 1.5 to 2%. If more camber is needed for soaring and distance flights, flaps should be used. The effect of flaps will not be considered here.

Three wings with different sections have been compared in Figures 1 & 2, and Tables 1 & 2. It is emphasised that the three profiles were tested in three different laboratories (Stuttgart, Princeton and ISF). We are comparing the incomparable. Even so, the result is of interest.

One of the more promising wing plans emerging from the 1986 study, for an F3B contest sailplane, was that shown here in Figure 1. When using the Quabeck HQ1.5/9 section it seemed to produce the best all round performance. With a relatively large wing area and moderate aspect ratio, it would be capable of carrying ballast for the speed task, and could be unloaded for the soaring task.

Now a comparison has been made with two other profiles, the Selig Donovan

8000 and the Rolf Girsberger 12. The wing plan, model weight, etc., remain identical.

Three performance tables are given, and the chart, Figure 2, shows the polar curve of the three wings superimposed one on the other.

Allowing for all the likely errors mentioned above, the three sections would in practice give virtually identical results. The HQ 1.5/9 might seem slightly superior at high speeds but the SD 8000 appears to have a small advantage at the lowest speeds. SD 8000 has, in fact, slightly more camber than either of the others and this shows up a little at the slow speed end of the chart. The Girsberger section falls between the other two at the extremes of fast and slow, but is slightly worse at intermediate airspeeds.

Even so, these are all very small differences. Given all the margins for error, it is highly improbable that the pilot would be able to detect any differences in performance.

Next we take the same basic wing plan and try it with three sections all tested in the one laboratory, Princeton. The chart (Figure 3) and performance polar figures in Table 3 are given. Wing 1 (SD 8000) is retained on the chart for comparison.

At low speeds there is nothing to choose between these four wings. At high speeds, above 20 m/s, (72 km/h or 45 mph) the polars tend to fan out. The SD 7003 wing shows some superiority over the others, with the Quabeck 2/9 section next best, the SD 8000 third and the Girsberger 15 fourth. Yet going back to the previous chart, the SD 7003 wing seems only very marginally better than the HQ 1.5/9. At the maximum speed calculable by this method, the glide ratio of the HQ 1.5/9 wing is 13.52, the SD 7003 is 13.82.

Within the range of probable wind tunnel errors, and allowing for inevitable inaccuracies in construction, it is most doubtful if any real difference could be detected, in flight, between any of these sections. If there is any margin, it seems likely to occur in the F3B speed task. There is no guarantee of this, however. What does appear fairly obvious is that there are no measurable differences between the different profiles at low and moderate speeds, such as are used for soaring and F3B distance task flying.

It is not likely that any of the sections would respond better to flaps than the others.

The question arises, if there are such slight differences between wing sections, what can be done to improve sailplane performance?

The obvious answer is, to increase the size of the model. For F3B contest flying this is impractical, since so much depends on the ability to make high speed turning manoeuvres and accurate spot landings. This requires a relatively small and manoeuvreable model. A span of 3 metres is about as large as anyone is prepared to go. There is also the absolute necessity of getting a very high, very fast launch, so the model must not be too heavy.

Nevertheless, the benefits of increasing size are worth illustrating. In Figures 4 & 5, and Tables 4 & 5, the performance of a large wing of 6 metres span and aspect ratio 18, is shown. The wing loading has been kept the same as for the smaller models, which results in a model mass of 8.6 kg. Such model sailplanes are commonly flown now, although requiring special permits in many countries.

The chart shows there is no advantage at high speeds. The benefit comes at the low speed end of the chart. Over a range of airspeeds from very low to moderately fast, the large model is

superior to the smaller one with the same wing section and the same wing loading. Of course, if the model were ballasted to an even higher weight, its speed performance would improve at some cost in soaring ability.

The larger model is clearly intended for soaring and cross country flying, it is not likely to succeed in the F3B contest.

Finally, for the sake of amusement as much as anything, the last chart (Figure 6) and Table 6 show what happens if a fully symmetrical wing section, the SD 8020, is used.

Clearly, the low speed performance suffers. This could be helped if flaps were used to increase the effective wing camber to 1 or 2%. At high speeds, the symmetrical profile has a distinct advantage over the SD 8000, though not so much over the HQ1.5/9. Such a model would nevertheless be a serious competitor in the F3B speed trials.

Some years ago, the F3B competition was usually decided by the two lap speed task. Duration and distance tasks had become almost superfluous since everyone in contention scored maximum points for these. The power of the winch was nearly as important as the model.

In 1980 I wrote an article in an Australian magazine suggesting that the F3B model should use a thin symmetrical wing section for the speed task. Flaps would be needed for the other tasks and launching.

The idea was to avoid the losses caused by making the normal steep turn between the two laps of the speed task and to reduce drag to a minimum in the accelerating dive before entering the measured course.

The model would dive vertically to gain speed, enter the course at suitable height and instead of banking to turn at Base B (thus increasing the wing drag

considerably and slowing the model down), the pilot should perform a bunt and **fly back to Base A inverted**. This, it seemed, would reduce losses to a minimum. Far from slowing down at the turn reversal, the bunt would cause the model to accelerate. (Better than rolling the model inverted before the reversal, which causes some increase in drag.)

A model along these lines was in fact built by Stefan Smith, a member of the Australian team at this period. Although it seemed to perform well in speed tasks, he did not persist with the development.

I have often wondered what would have happened if this idea had caught on. Perhaps it is not too late.

SOARTECH SAILPLANE WING DESIGN EXERCISE

Span: 3.000 m Aspect ratio:11.0
 Mass: 3.520 kg Weight:34.52 Newtons
 Wing area: 0.818 sq m Wing loading: 4.302 kg/sq.m
 Root chord: 33.50 cm.
 Chord at taper break: 29.25 cm
 Tip chord: 16.75 cm.
 Standard mean chord: 27.27 cm.
 Aerodynamic mean chord:31.42 cm
 Taper break: 0.765 metres from centre line.
 Washout: 0 degrees Taper ratio 0.5
 Slope of lift curve in radians 5.04

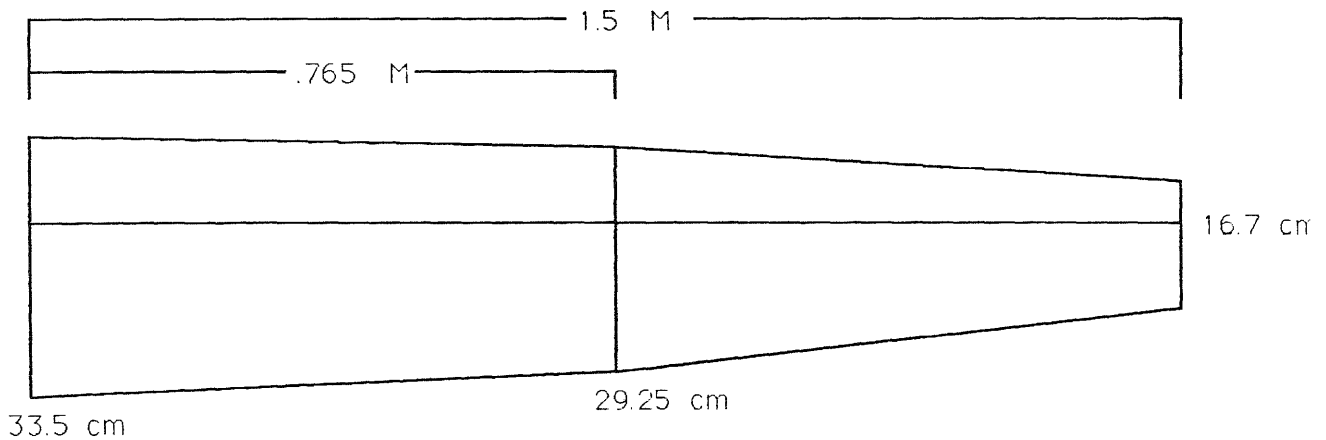
GEOMETRICAL CHARACTERISTICS OF EXAMPLE WING

2y/b	Chord, m.	ROOTCHORD/C	Sin O	Incidence
0.0000	0.335	1.0000	1.0000	0.00
0.1564	0.322	1.0405	0.9877	0.00
0.3090	0.309	1.0832	0.9511	0.00
0.4540	0.297	1.1273	0.8910	0.00
0.5878	0.273	1.2285	0.8090	0.00
0.7071	0.242	1.3829	0.7071	0.00
0.8090	0.216	1.5492	0.5878	0.00
0.8910	0.195	1.7152	0.4540	0.00
0.9511	0.180	1.8612	0.3090	0.00
0.9877	0.171	1.9632	0.1564	0.00

TABLE 1.

SKETCH OF THE PLANFORM FOR WING 1 SOARTECH

Aspect ratio 11 Taper ratio 0.50 Mean chord 27.3cm.



Washout 0 deg. Mass 3.520 Kg. Wing loading 4.30 Kg/sq.m.

FIGURE 1.

TABLE 2.

PERFORMANCE POLAR FOR SOARTECH WING NUMBER 1

Profile SELIG DONOVAN 8000 Wing loading = 4.30 kg/sq.m.
 Span = 3.00 metres. Aspect ratio = 11
 Root Chord = 33.50 cm. Mid Chord = 29.25 cm. Taper ratio = 0.50

Velocity Metres/Sec	Sink M/sec	L/D Ratio
26.25	2.139	12.27
18.56	0.796	23.32
15.15	0.520	29.16
13.12	0.414	31.74
11.74	0.375	31.31
10.71	0.369	29.07
9.92	0.367	27.03
9.28	0.380	24.41
8.75	0.394	22.20
8.30	0.416	19.96
7.91	0.915	8.65

PERFORMANCE POLAR FOR SOARTECH WING NUMBER 2

Profile H. Quabeck 1.5/9 Plain Wing loading = 4.30 kg/sq.m.
 Span = 3.00 metres. Aspect ratio = 11
 Root Chord = 33.50 cm. Mid Chord = 29.25 cm. Taper ratio = 0.50

Velocity Metres/Sec	Sink M/sec	L/D Ratio
26.25	1.942	13.52
18.56	0.808	22.95
15.15	0.540	28.06
13.12	0.454	28.90
11.74	0.400	29.31
10.71	0.367	29.16
9.92	0.374	26.54
9.28	0.393	23.64
8.75	0.426	20.53
8.30	0.890	9.32

PERFORMANCE POLAR FOR SOARTECH WING NUMBER 3

Profile Girsberger 12 Wing loading = 4.30 kg/sq.m.
 Span = 3.00 metres. Aspect ratio = 11
 Root Chord = 33.50 cm. Mid Chord = 29.25 cm. Taper ratio = 0.50

Velocity Metres/Sec	Sink M/sec	L/D Ratio
26.25	2.076	12.64
18.56	0.878	21.14
15.15	0.585	25.89
13.12	0.463	28.35
11.74	0.414	28.38
10.71	0.389	27.55
9.92	0.382	25.99
9.28	0.412	22.53
8.75	0.485	18.05
8.30	0.752	11.03

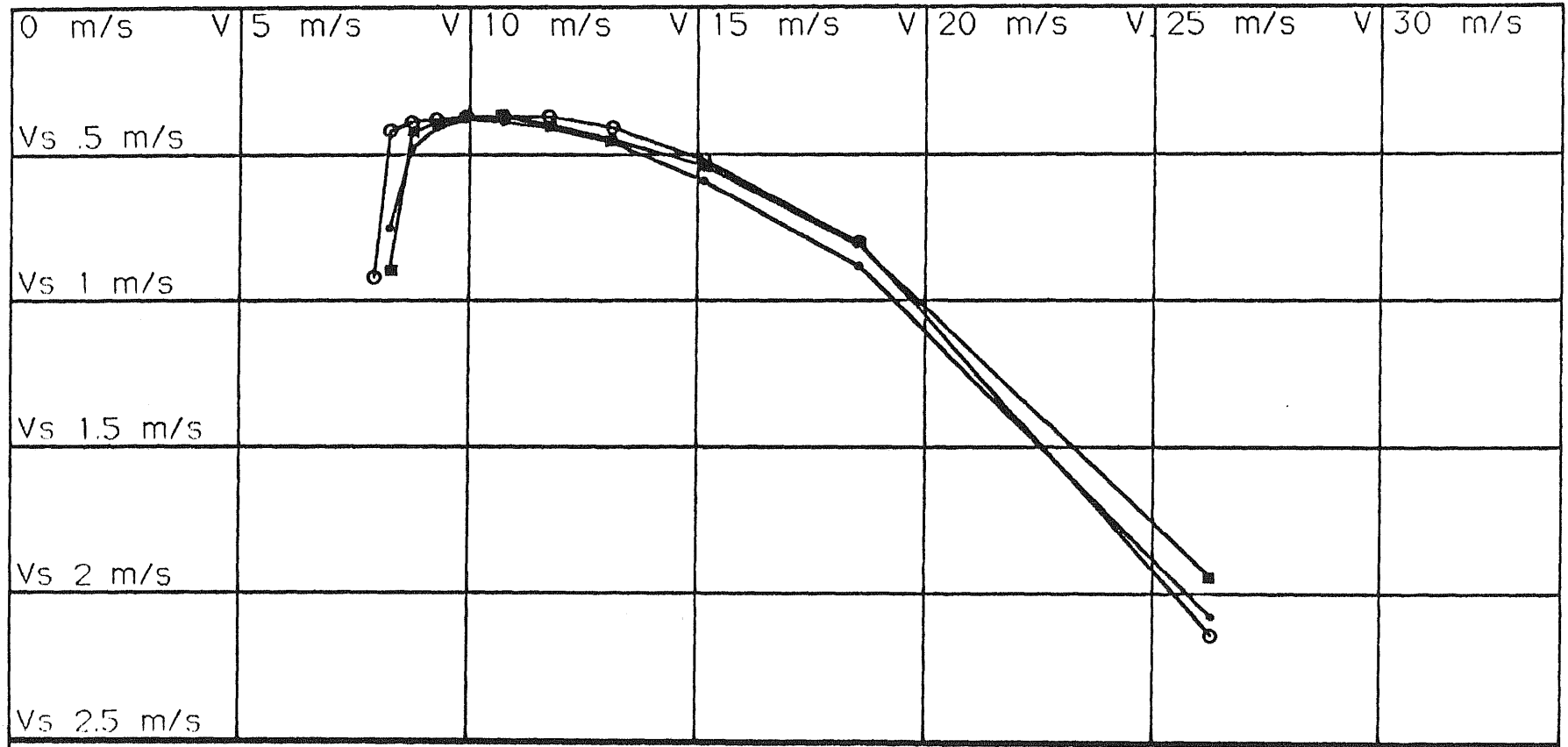


FIGURE 2.

POLARS

- WING 1. SD-8000
- WING 2. HQ 1.5/9
- WING 3. GIRSBERGER RG-12

TABLE 3.

PERFORMANCE POLAR FOR WING NUMBER 4

SELIG DONOVAN 7003 Wing loading = 4.30 kg/sq.m.
 Span = 3.00 metres. Aspect ratio = 11
 Root Chord = 33.50 cm. Mid Chord = 29.25 cm. Taper ratio = 0.50

Velocity Metres/Sec	Sink M/sec	L/D Ratio
26.25	1.899	13.82
18.56	0.752	24.67
15.15	0.520	29.16
13.12	0.432	30.40
11.74	0.395	29.71
10.71	0.381	28.11
9.92	0.384	25.81
9.28	0.394	23.58
8.75	0.422	20.75
8.30	0.813	10.21
7.91	0.916	8.64

PERFORMANCE POLAR FOR SOARTECH WING NUMBER 5

Profile GIRSBERGER 15 - PT Wing loading = 4.30 kg/sq.m.
 Span = 3.00 metres. Aspect ratio = 11
 Root Chord = 33.50 cm. Mid Chord = 29.25 cm. Taper ratio = 0.50

Velocity Metres/Sec	Sink M/sec	L/D Ratio
26.25	2.226	11.79
18.56	0.798	23.26
15.15	0.496	30.52
13.12	0.412	31.82
11.74	0.372	31.55
10.71	0.362	29.59
9.92	0.369	26.86
9.28	0.383	24.22
8.75	0.355	24.62
8.30	1.003	8.27
7.91	0.944	8.39

PERFORMANCE POLAR FOR SOARTECH WING NUMBER 6

Profile QUABECK 2/9A-PT Wing loading = 4.30 kg/sq.m.
 Span = 3.00 metres. Aspect ratio = 11
 Root Chord = 33.50 cm. Mid Chord = 29.25 cm. Taper ratio = 0.50

Velocity Metres/Sec	Sink M/sec	L/D Ratio
26.25	2.050	12.80
18.56	0.776	23.92
15.15	0.525	28.84
13.12	0.412	31.85
11.74	0.372	31.52
10.71	0.357	30.00
9.92	0.356	27.90
9.28	0.382	24.31
8.75	0.413	21.21
8.30	0.558	14.86
7.91	0.917	8.63

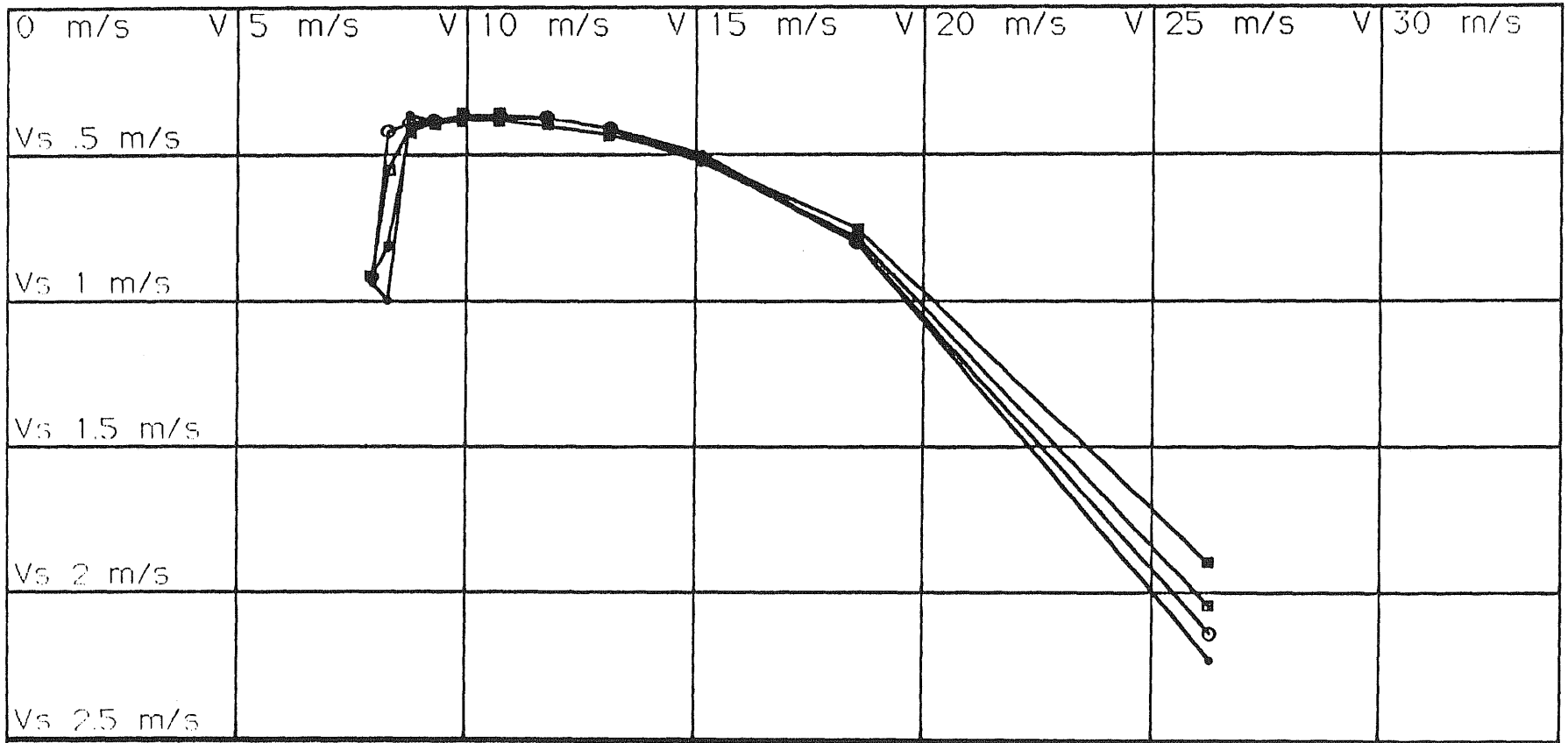


FIGURE 3.

POLARS

- WING 1. SD-8000
- WING 2. GIRSBERGER RG-15
- WING 3. HQ-2/9A
- WING 4. SD-7003

SOARTECH SAILPLANE WING DESIGN EXERCISE

SELIG DONOVAN 8000

SOARTECH 8 FIGURE 12.152

Span: 6.000 m Aspect ratio:18.0
 Mass: 8.600 kg Weight:84.34 Newtons
 Wing area: 2.000 sq m Wing loading: 4.300 kg/sq.m
 Root chord: 40.00 cm.
 Chord at taper break: 34.00 cm
 Tip chord: 16.00 cm.
 Standard mean chord: 33.33 cm.
 Aerodynamic mean chord:37.08 cm
 Taper break: 2.083 metres from centre line.
 Washout: 3 degrees Taper ratio 0.4
 Slope of lift curve in radians 5.04

GEOMETRICAL CHARACTERISTICS OF EXAMPLE WING

2y/b	Chord, m.	ROOTCHORD/C		Sin θ	Incidence
0.0000	0.400	1.0000	1.0000	3.00	
0.1564	0.386	1.0350	0.9877	3.00	
0.3090	0.373	1.0715	0.9511	3.00	
0.4540	0.361	1.1087	0.8910	3.00	
0.5878	0.349	1.1454	0.8090	2.47	
0.7071	0.333	1.2029	0.7071	1.76	
0.8090	0.273	1.4679	0.5878	1.15	
0.8910	0.224	1.7841	0.4540	0.65	
0.9511	0.189	2.1183	0.3090	0.29	
0.9877	0.167	2.3916	0.1564	0.07	

TABLE 4.

SOARTECH SKETCH OF THE PLANFORM FOR WING 2

Date 03-23-1993 Time 19:50:01

Aspect ratio 18 Taper ratio 0.40 Mean chord 33.3cm.

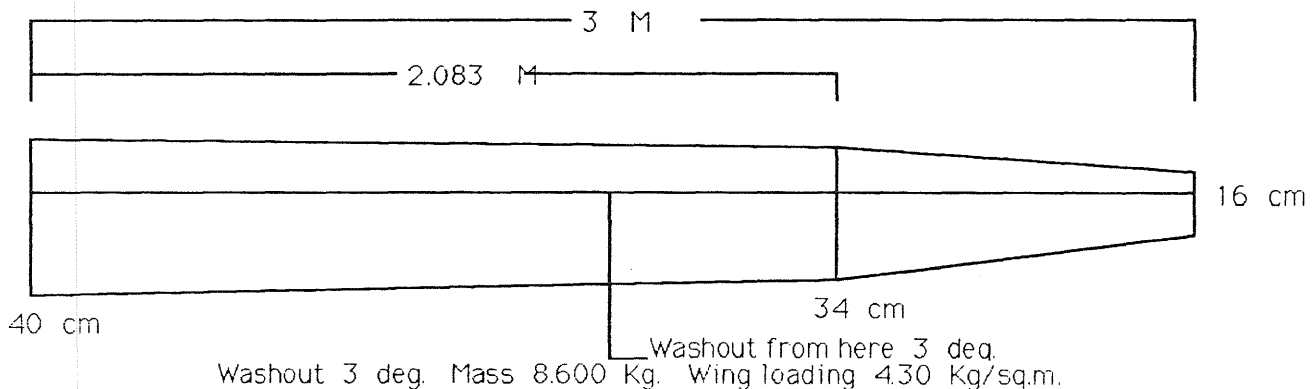


FIGURE 4.

PERFORMANCE POLAR FOR SOARTECH WING NUMBER

Profile SELIG DONOVAN 8000 Wing loading = 4.30 kg/sq.m.
 Span = 6.00 metres. Aspect ratio = 18
 Root Chord = 40.00 cm. Mid Chord = 34.00 cm. Taper ratio = 0.40

Velocity Metres/Sec	Sink M/sec	L/D Ratio
26.24	2.112	12.42
18.55	0.744	24.95
15.15	0.446	33.95
13.12	0.330	39.72
11.73	0.305	38.53
10.71	0.287	37.27
9.92	0.282	35.11
9.28	0.287	32.36
8.75	0.295	29.66
8.30	0.312	26.56
7.91	0.716	11.06

TABLE 5.

PERFORMANCE POLAR FOR SOARTECH WING NUMBER 2

Today's date 03-23-1993 Time of run 21:49:32

Profile SELIG DONOVAN 8020 Wing loading = 4.30 kg/sq.m.
 Span = 3.00 metres. Aspect ratio = 11
 Root Chord = 33.50 cm. Mid Chord = 29.25 cm. Taper ratio = 0.50

Velocity Metres/Sec	Sink M/sec	L/D Ratio
26.25	1.787	14.69
18.56	0.829	22.39
15.15	0.547	27.71
13.12	0.467	28.12
11.74	0.438	26.83
10.71	0.440	24.37
9.92	0.444	22.32
9.28	0.955	9.72

TABLE 6.

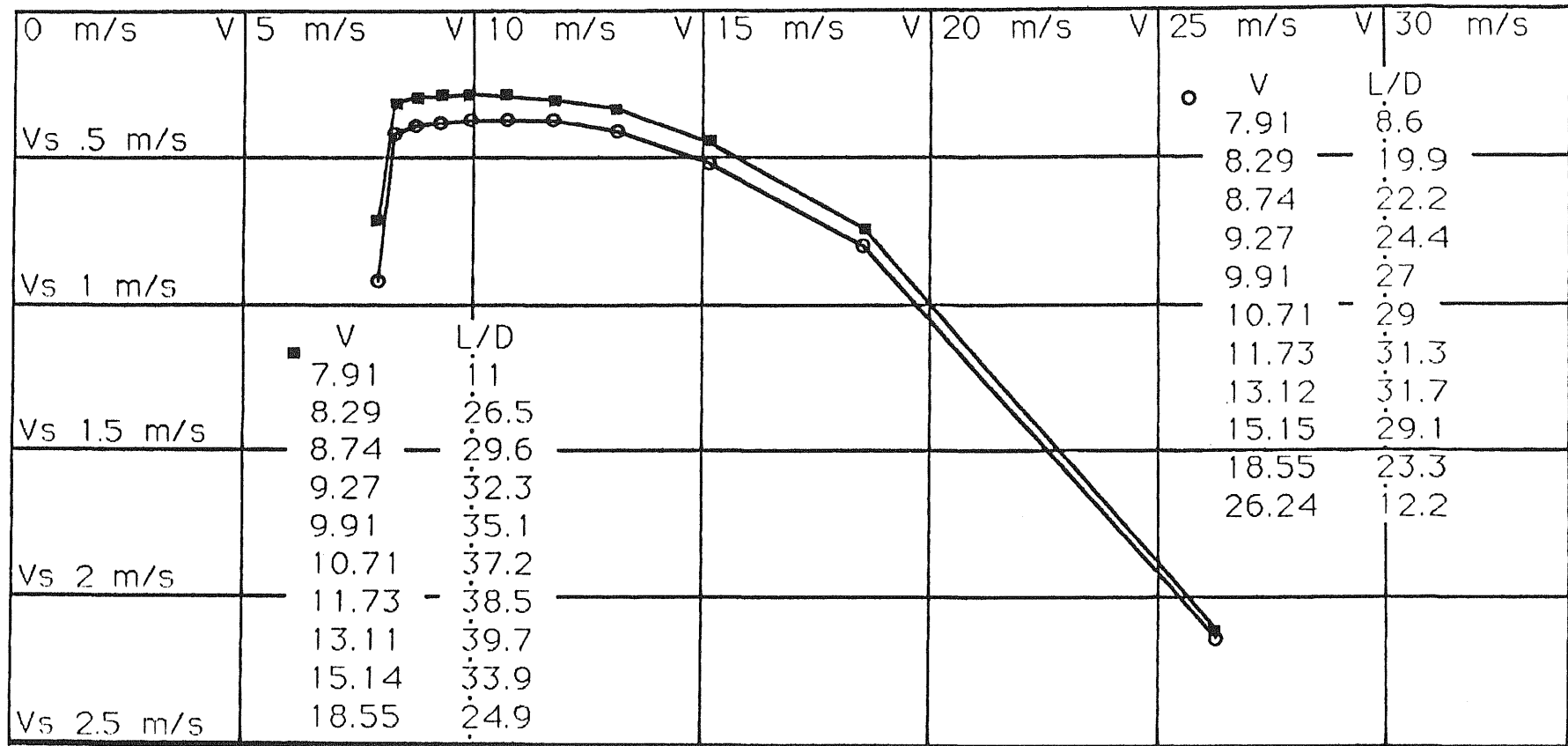


FIGURE 5.

○ B=3.0m A.R.=11 M=3.5Kg W/S=4.3Kg/sq.m.

■ B=6.0m A.R.=18 M=8.6Kg W/S=4.3Kg/sq.m.

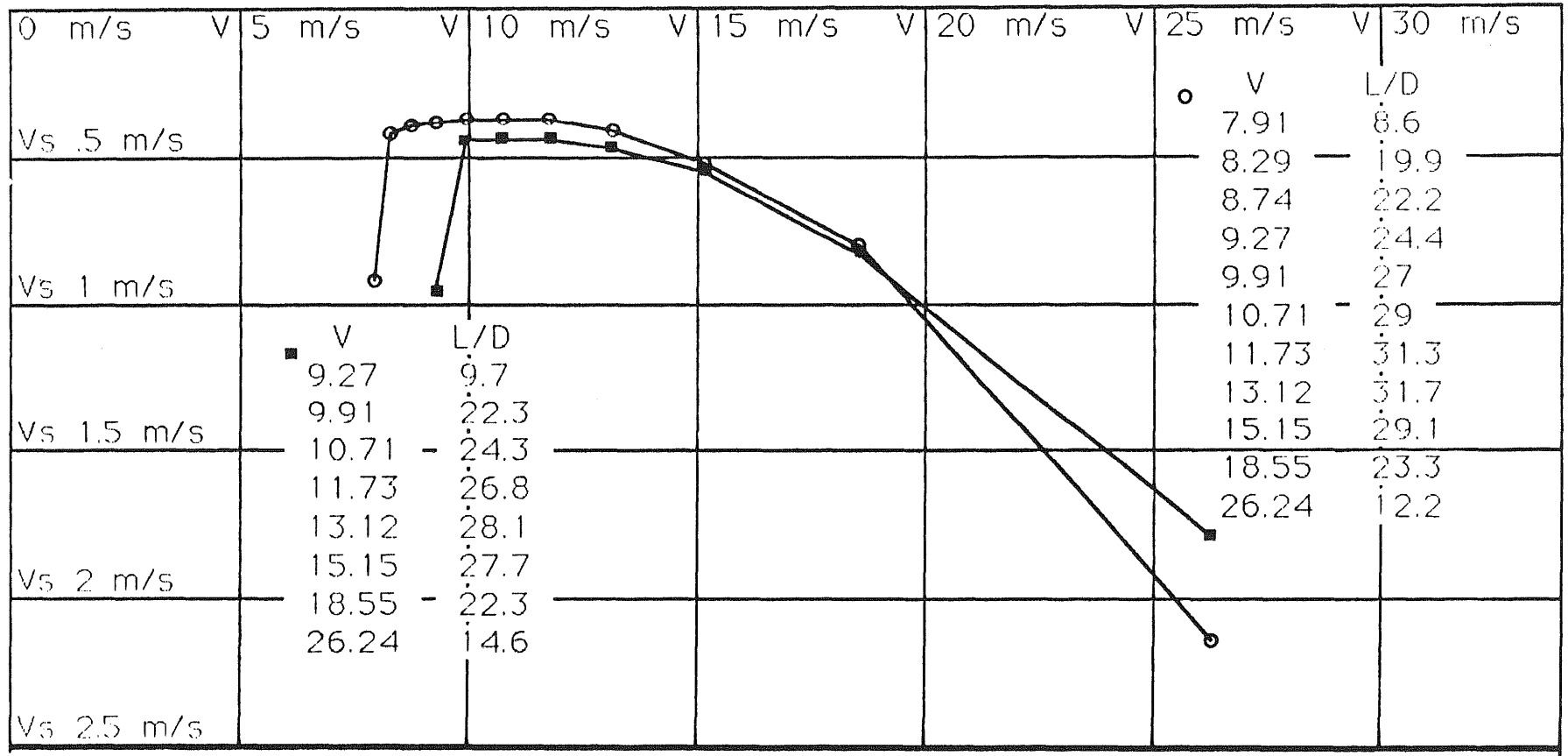


FIGURE 6. ○ B=3.0m A.R.=11 M=3.5Kg W/S=4.3Kg/sq.m.

■ B=3.0m A.R.=11 M=3.5Kg W/S=4.3Kg/sq.m.

ISF Seminar

1991 TOWING MODEL SAILPLANES BY ELECTRIC POWERED WINCH

by V. & L. De Filippis

1.0 INTRODUCTION

The altitude which is achieved during the towing and the following levelling manoeuvre considerably affects the task performance of the model sailplanes.

The configuration of the F3B gliders in the past was also influenced by the lack of winch limitations.

The line tension limitation by the weak-link, but mainly the winch power limitation was introduced to reduce the influence of towing on the task results. In effect, the present altitudes reached during the launch are lower than in the past.

The model configuration changes resulted in a slight reduction in the wing surface. The towline tension reduction led to lower structural stress. This effect, combined with the reduced model dimension, resulted in a reduction in the weight.

At first sight, the changes seem to be quite conservative and preliminary.

Given this scenario, we decided to explore the possibilities of finding a calculation tool in order to determine the altitude attained during the launch. By developing a few appropriate programs, we could eventually evaluate by calculating the task performances and verifying the present configuration changes of the F3B gliders are really the optimum solution.

1.1 PURPOSE

The purpose of this paper is to propose a tool in order to achieve three main objectives.

The first objective is that this tool shall provide the capability for evaluating the altitude a glider may reach during the launch.

Secondly, provide the capability for exploring the applicable towing technics.

Finally, identify the towing strategy (attitude/speed) to reach the highest altitude at the end of the launch.

1.2 SCOPE

The target is to utilize the above mentioned results in defining or comparing the design configuration of a F3B glider.

In addition, we should have a rational when choosing the task configuration (flaps position, ballast weight) more suitable to each specific F3B task.

2.0 TOWING

Prior to performing a quantitative analysis, a qualitative overview of the actions and the effects should be helpful either by local detailed analysis or by global evaluation using energetic considerations.

2.1 PRELIMINARY ANALYSIS

Launching the gliders is a transient phase. Many functions are interacting and the value of the parameters continuously change during the climb and the pilot's manoeuvres.

The interactions are analysed by simplified schemes and a few assumptions are introduced to reduce the complexity of the mathematical model. Moreover it is supposed that the pilot is able to keep or change the model's attitude as required by the strategy that is imposed or as required by the optimization process.

During towing, the towline forces the model to move forward because the towing operator pulls the end of the line or because the winch shortens the line by winding the wire on a drum. The upward motion is obtained by increasing the attitude and/or the speed of the glider over the values used in the level flight.

The model is forced to move along the ascending path due to the force which is applied by the towhook in the direction of the motion. The entire force applied by the line isn't helpfull for the motion, except for the part acting along the direction of the movement. The component which is perpendicular to the trajectory is useless. It has to be balanced by the wing lift, therefore it produces drag and dissipates some energy that is spent to make the glider climb (see FIG. 1).

If the towing is performed by hand, the loss of energy doesn't considerably affect the altitude at the end of the towing, because it is possible to continue the towing as long as the model is not directly above the head of the towing operator. On the contrary, if a winch is used, we are forced to stop the towing and any energy supply when the model is directly over the point where the winch return pulley is installed. Therefore, it is advantageous to minimize any loss of energy, in particular the loss caused by the drag which is "induced" by the tension of the towline, by selecting the appropriate attitude for the model.

2.2 SYSTEM GLIDER + TOWLINE

During towing, the sailplane is linked to the ground by the towline. The line forces the model to climb by applying a traction through the towhook. However, the model makes the towline climb overcoming the air drag and the weight of the wire.

The model is strictly interacting with the towline. Therefore, from now on, we will analyse the global system made by the glider, the towline and related parachute or equivalent devices.

2.3 ENERGY SUPPLY

The amount of energy the winch is able to supply during a given time interval may be calculated by multiplying the

tension of the line (the average value if the tension isn't constant in the interval) and the length of the line the winch drum has wound during the examined time interval. The total amount of energy the winch can supply during towing is obtained by adding the energy supplied during each interval from the time the towing starts until the glider is released.

During towing, it is helpful to supply as much energy as possible and to maximize the energy supplied during each of the above mentioned intervals.

The maximum altitude possible to reach during towing is equal to the line length at the release moment. Therefore, before releasing the model, the winch should wind the least possible quantity of wire. In consequence, to obtain the largest quantity of energy from the winch, it is necessary to maintain as long as possible the highest towline tension compatible with the model's strength.

Moreover, the power required from the winch is obtained by multiplying the line tension and the winding speed.

Therefore, if the value of the line tension is fixed, and it is assumed that the winch motor has to run within the maximum power range, the winding speed is identified and the diameter of the winch drum may be calculated.

On the other side, the glider speed along the trajectory and the winding speed are strictly subordinate. Indeed, the motion of the glider along the trajectory may be considered compound by two instantaneous motions as follows:

- a rotation around the point where the return pulley is placed
- a motion along the line toward the return pulley, which is caused by the line winding.

Therefore, the component of the model speed along the line toward the return pulley is the winding speed.

The attitude of the glider remains to be determined. The loss of energy is the lowest when the model flies at the attitude where the CL/CD ratio is maximum. However, as previously mentioned, it is the CL/CD ratio of the system glider + towline that has to be considered.

Even if the length of the line changes during the tow and the line speed isn't constant both along the line and during the tow, it is possible to calculate a average value and to evaluate it as an increment of the aerodynamic drag of the glider. The calculation, not included in this document, are based on the present more common glider/towline configurations. The results show an increment of CD caused by the towline (referred to the whole model) which is considerably higher than the minimum CD of the glider alone. Therefore, the max CL/CD value of the system glider + towline is displaced toward the maximum CL, and when the flaps are used, it is displaced toward the maximum CL of the deflected flap configuration (see FIG. 2).

Continuing the analysis, the speed of the glider at the end of the towing phase is usually higher than the one used in the following phase. Additional altitude is usually gained by climbing and reducing the speed to the operational value.

Therefore, the previous evaluation of the best model attitude has to be reviewed.

If part of the energy supplied for the altitude gain is used to increment the speed of the glider at the end of the tow, we could obtain higher final altitude by reducing the speed after the release. Of course, the process requires many trials prior to obtaining the optimum result.

The last consideration suggests reviewing the whole process in order to consider the dynamic effects and to integrate the final climb in the evaluation process.

2.4 DYNAMIC ANALYSIS

The analysis will be performed by examining the actions of each force and the following effects including the inertia forces. FIG. 3 shows the forces which affect the system made by the glider and the towline.

The line traction TM makes the glider accelerate along the trajectory. The related inertia force IF is directed backward and joins with the aerodynamic drag R .

The vertical component of the traction TMV joins with the model's weight Q .

Also a part of the model's drag R joins with the model's weight.

The lift P forces the glider to move and accelerate upward, even if the horizontal component is directed in the opposite of the motion like the aerodynamic drag.

The drag from the towline RC is partially directed downward and backward.

Moreover, the bending of the trajectory generates a centrifugal force CF that is directed radially and upward.

With regard to the winch actions, the previous considerations remain substantially the same. The winch traction TM is required to balance also the inertia force of the glider.

3.0 MATHEMATICAL MODEL

3.1 ASSUMPTION

Schemes and simplifying assumptions are used to approximate the actual glider trajectory during towing, actual characteristics of the glider and towing equipment. They are hereafter listed and detailed.

3.1.1 CLIMB PATH DURING TOWING

The climb path is approximated by a sequence of straight and relatively short movements (one hundred steps are considered).

3.1.2 CLIMB PATH DURING LEVELLING MANOEUVRE

The climb is assumed vertical after the towline is released.

The attitude is assumed close to zero lift.

The losses of energy caused by the pull up after the towline is released and by the pitch down for levelling the flight are disregarded.

3.1.3 GLIDER + TOWLINE SYSTEM

As previously mentioned, the line between the glider hook and the return pulley is considered like an integral part of the glider. In this way, the force that the towline applies to the glider does not have to be determined.

3.1.4 TOWLINE

It is assumed that the towline is not elastic. Therefore, it is not lengthened by the line tension. In consequence, the towing impulse technique ("stop and go") which sometimes is used to limit the line tension and to continue the climb using the elastic contraction of the line, is not applicable.

Moreover, the towline is curved due to the air drag while the traction at the return pulley is assumed to be directed toward the glider. However, the difference is enough small to be disregarded.

3.1.5 WINCH EQUIPMENT

It is assumed that the electric motor of the winch runs continuously since the release of the model until the release of the line, in order to use the whole power the motor can supply.

The diameter of the winch drum is assumed fixed during towing.

The speed vs torque characteristics of the electric motor is approximated by a straight line within the maximum power range.

3.1.6 FORCES ACTING ON THE GLIDER

It is assumed that the towline doesn't induce appreciable moment because the position of the towhook is supposed to be along the straight line that is directed from the model's center of gravity tangent to the towline.

It is assumed that the resultant of the aerodynamic forces is acting on the center of gravity of the glider and the resultant moment is small enough to be disregarded.

The drag of the fuselage, tail section and the interference drag are introduced by a coefficient which is derived by parametric evaluations on real scale sailplanes.

The CL/CD polar of the wing section is approximated by a geometric simplified scheme.

The model Reynolds number during the launch is assumed constant (an average value is selected and refers to the average geometric wing chord of the glider and to the average presumed speed during the towing phase).

The HQ 2.5/9 wing section data (Stuttgart windtunnel data, 1983) are listed and used as example. It is assumed that the flaps are used. They are progressively retracted during towing. Therefore, the envelopment of the CL/CD polars which refer to several deflection angles is used.

3.1.7 WIND ACTION

Only tailwind or headwind conditions are considered. Side components of the wind and changes with the altitude are not considered.

4.0 COMPUTING METHODOLOGY

The classic approach to solve the dynamic problem is applied. At each instant, the forces acting on the glider + towline system are counterbalancing, that is the addition (vectorial resultant) of all the forces is null (the resultant moment is assumed negligible).

For the convenience of calculation, each force is considered as the addition (vectorial) of a horizontal and a vertical component. Therefore, the forces are counterbalancing when both the addition of the horizontal components and the addition of the vertical components are null.

The first step requires calculating the forces and their horizontal and vertical components which affect the system made by the glider and the towline.

The forces depend on the speed and accelerations of the glider because :

- the aerodynamic forces depend on the model speed
- the inertia forces depend on the model accelerations
- the towline force depends on the winding speed which in turn depends on the speed of the model.

However, the speed and the accelerations of the model depend on the distance travelled in a given time interval and on their changes.

Therefore, hereafter, we will provide the details of the mathematical relations which link the space and time intervals to speed, accelerations and finally the forces.

4.1 GLIDER'S TRAJECTORY (FIG. 4)

The climb path during towing is approximate by a sequence of straight and relatively short movements. For the convenience of calculation, the movement of the glider along the climb trajectory is determined by adding the horizontal movement DX and the vertical movement DZ.

The movements DX and DZ are referred to ground. The glider's horizontal position X and the vertical position Z refer to the point where the glider is released.

1,2,3 points are a few subsequent positions reached by the model during towing. DT is the time elapsed to cover the distance within two subsequent positions.

SB and CB are the functions sin and cos of the B angle which will be used further on.

4.2 GLIDER'S SPEED

Both the true and indicated speed are required by the calculation when the effect of the wind is considered.

because the aerodynamic forces depend on the indicated airspeed, while the inertia forces depend on the true airspeed changes. When the wind is absent the values of the true and indicated airspeed are equal.

The true airspeed is determined by the graphical and mathematical methods shown in FIG. 5, while the method for determining the indicated airspeed is illustrated in FIG. 6.

4.3 GLIDER'S ACCELERATIONS AND INERTIA FORCES (FIG. 7)

The acceleration which is tangent to the trajectory is calculated assuming that during each interval the change of the direction of the speed is negligible. Therefore, the movement of the model is assumed to be straight. Moreover, the motion is assumed to be uniformly accelerated. The method for the calculation of the tangential acceleration and inertia force is shown in FIG. 8.

The centrifugal acceleration is caused by the rotation around the point where the return pulley is placed. The tangential speed of the motion is a component of the model's speed. The centrifugal acceleration and force FC are calculated by the usual formulae (see FIG. 8).

4.4 TOWLINE'S DRAG (FIG. 9)

The aerodynamic drag of the towline is calculated by the integral shown in the figure. The component of the (indicated) airspeed perpendicular to towline is used for the drag computation.

The Reynolds number changes along the towline due to the change of the airspeed along the line. It is equal to the speed of the glider close the hook and becomes null close the return pulley. However, the CD of the line for the most common wire diameters and range of speed remains rather constant (see FIG. 9). Therefore, the calculations are performed by assuming an average value of CD .

4.5 GLIDER'S LIFT AND DRAG (FIG. 10)

The lift and the drag of the wing are calculated by the usual formulae. The drag of the fuselage, tail section and interference drag are introduced by a corrective coefficient which increase the value of the wing section drag.

The CL/CD polar of the wing section is approximated by the simplified scheme shown in FIG. 11. As previously assumed, the polar data refer to a fixed average value of Reynolds number. The approximation is acceptable during towing because the wing section drag is relatively small in confront of the CD due to the system made by the glider and the towline.

The same data are used for the calculation of the climb after the towline is released, when the speed and consequently the Reynold number decrease considerably. However, the increment of the section drag is enough balanced by the CD value which is assumed in the simplified scheme.

4.6 WINCH TRACTION

FIG. 12 shows the standard characteristics of a DC electric motor. For the convenience of calculation, the speed (rpm) and torque characteristics is used.

The characteristics is approximate by a straight line within a quite wide power range (+/- 30 % of the maximum power rpm). Therefore, the torque C and the traction TR can be obtained by the approximate expression shown at FIG. 12.

The loss of energy due to the mechanical drags of the winch system is introduced by a coefficient FRP which affects the available traction TR.

4.7 EQUILIBRIUM FORCES EQUATIONS

The mathematical expressions shown in FIG. 4 and subsequent are used for writing the equilibrium forces equations.

The resultant of the horizontal components of the forces FX and the resultant of the vertical components of the forces FZ are :

$$\begin{aligned}FX &= IX + FCX + PX + RX + RCX + TMX \\FZ &= -Q + IZ + FCZ + PZ + RZ + RCZ + TMZ\end{aligned}$$

These expressions are the core of the mathematical model. They are collected at Pag. 15 and form the main subroutine of the computer program. Finally, the forces equilibrium is reached when both the horizontal resultant and the vertical resultant of the forces are null, that is:

$$\begin{cases}FX = 0 \\FZ = 0\end{cases}$$

5.0 COMPUTING PROCEDURES

The procedures for solving the above mentioned system of equations are shown hereafter.

Moreover, a procedure for identifying the towing strategy to reach the highest altitude at the end of the launch is analysed.

5.1 CLIMB PATH DURING TOWING

5.1.1 ASSUMPTIONS

The CL and the length L of the towline are assumed constant within each interval. The values of the airspeed (true and indicated) and the winding speed VA are the average values of each interval. Therefore, the aerodynamic forces and the tension of the towline are average values.

5.1.2 OVERVIEW OF THE PROCEDURES

For each interval of towing, a couple of unknown values (space interval and time interval) have to be determined by trials to satisfy the equilibrium force equations. By performing appropriate methodologies, the number of the trials can be reduced.

The operations required for each interval are hereafter listed.

- 1- Fix the initial position and the initial speed of the glider.
- 2- Presume the position where the glider will be after a presumed time interval.
- 3- Calculate the speed, acceleration, inertia forces and aerodynamic forces.
- 4- Check whether the forces counterbalance within the fixed approximation range.
- 5- If not, change the presumed position and time interval and repeat the calculation until the equilibrium of the forces is achieved.

5.1.3 PROCEDURES DETAILS

The step-by-step calculation is shown hereafter.

- 1 - The preliminary value of the vertical movement executed during the first interval is presumed null. Also, the preliminary value of time interval is presumed (.03 s is suggested). These two preliminary values are introduced in the horizontal equilibrium force equation ($F_X = 0$). If the equation isn't satisfied, the time interval is increased or decreased until the value of the resultant force F_X is null or within the fixed approximation range (± 0.1 kg is suggested).
- 2 - This time interval and a presumed vertical movement (0.5 m is suggested) are introduced in the vertical force equilibrium equation ($F_Z = 0$). If the equation isn't satisfied, the vertical space interval is increased or decreased until the value of the resultant force F_Z is null or within the fixed approximation range (± 0.1 kg)
- 3 - The value of the vertical movement is then introduced in the horizontal equilibrium force equation and a "new" value of the presumed time interval is determined just the same as 1 point.
- 4 - The "new" value of the time interval is then introduced in the vertical equilibrium force equation in order to identify the "new" vertical movement just the same as 2 point.

The calculation is repeated until both the equilibrium force equations are satisfied within the fixed approximation range (± 0.1 kg).

Therefore, the vertical movement and the time interval of the first step are known.

The values of the second and subsequent intervals are calculated in the same way.

The elapsed starting time is obtained by adding the time intervals.

The horizontal and vertical positions of the glider are obtained by adding the horizontal and vertical movements.

Moreover, when the equilibrium force equations are satisfied, the values of the other interesting parameters (global CL, glider speed, winding speed, towline tension) can be determined.

5.1.4 TOWLINE TENSION LIMITATION

The maximum towline tension is an input data which is required by the program.

If the tension obtained by the calculations is higher than the fixed one, the CL is progressively decreased and the calculation is performed again until the towline tension becomes equal to the maximum allowed value.

5.2 CLIMB PATH AFTER RELEASING TOWLINE (FIG. 13)

The climb is assumed to be straight, very steep (close to vertical) and performed at very low CL (about 0.1).

The total altitude which is reached by reducing the speed of the glider (from the time the towline is released until the operating value is reached) is calculated by energetic considerations. The loss of kinetic energy is used for increasing the potential energy (increase the altitude of the glider) and covering the work of the aerodynamic drags.

The total gain of the altitude is calculated by intervals. The changes in altitude are obtained by reducing the speed of a fixed amount (1 m/s is suggested). They are cumulatively added until the speed becomes equal to the operating value.

FIG. 13 shows the formulae used and rationales.

5.3 TOTAL ALTITUDE

Whatever the releasing point may be, the total altitude reached by the glider is obtained by adding the altitude reached by towing and the altitude gained by the levelling manoeuvre.

Therefore, the total altitude after launching is obtained by adding the altitude reached at the end of towing and the altitude gained by reducing the speed to the operating value.

5.4 TOWING STRATEGIES AND OPTIMIZATION PROCEDURE

In the procedure described in paragraph 5.1.2, it is assumed that the tow is performed at constant CL and the CL/CD ratio of the system made by glider and towline is maximum.

Conceptually the tow at constant CL is the simplest strategy and moreover, it is commonly selected for performing the first step of the climb.

However, as previously mentioned, the most advantageous trajectory to reach the highest altitude at the end of the launch might require performance at a lower CL. Moreover, the CL might change during towing.

Therefore, an iterative procedure is used to identify the trajectory to reach the highest possible total altitude by reducing the speed accumulated during the tow. It requires to repeat the calculation for the total altitude by reducing progressively the CL (0.01 step is suggested).

The calculation is complete when the value of the total altitude begins to decrease. The last CL obtained is the optimum. The calculation is repeated for each interval.

Usually the CL decrement results in speed increment, winding speed increment, towing traction decrement and in a lower trajectory. The limits for increment of speed depend on the strength and stiffness of the model, specially when there is strong wind. The usual practice "stop and go", that is to stop the winch motor for a short period, can't be simulated by the present program and the calculation continues even if the speed limits are overcome.

6.0 COMPUTER SOFTWARE

The Basic Language was selected to perform the numeric calculation program.

The solutions of the equations are obtained by trials. Even if appropriate methods reduce the number of the trials, the optimization processes (within acceptable approximation range) require consistent computer time when a medium power PC is used. Therefore, the use of a compiler program (eg. Turbobasic) is suggested to reduce the computer time.

7.0 CONCLUSIONS

The altitude achieved during the tow and the following levelling manoeuvre, considerably affects the task performance of the model sailplanes.

The paper describes a mathematical approach to predict the above mentioned altitude, through an approximate mathematical model and a rather easy program to be run on a conventional PC.

The purpose is to provide a tool to compare different model configurations.

The strategies of climbing by towing are analysed and the climbing after the release is simulated for computing the final altitude. An iterative process is used to determine the most usefull "dynamic" trajectory to reach the maximum altitude at any point of the trajectory.

The accuracy of the results depends on the approximation introduced by the mathematical model and on the selected approximation of the calculation.

Although the results compare quite well with the altitudes measured on the field, space remains for further improvements of the program considering for instance the elasticity of the towline.

In order to evaluate the worthiness of the method, the calculation's results of towing a model similar to Liese's "Epsilon" with different winch's characteristics are shown in the annexed graphics.

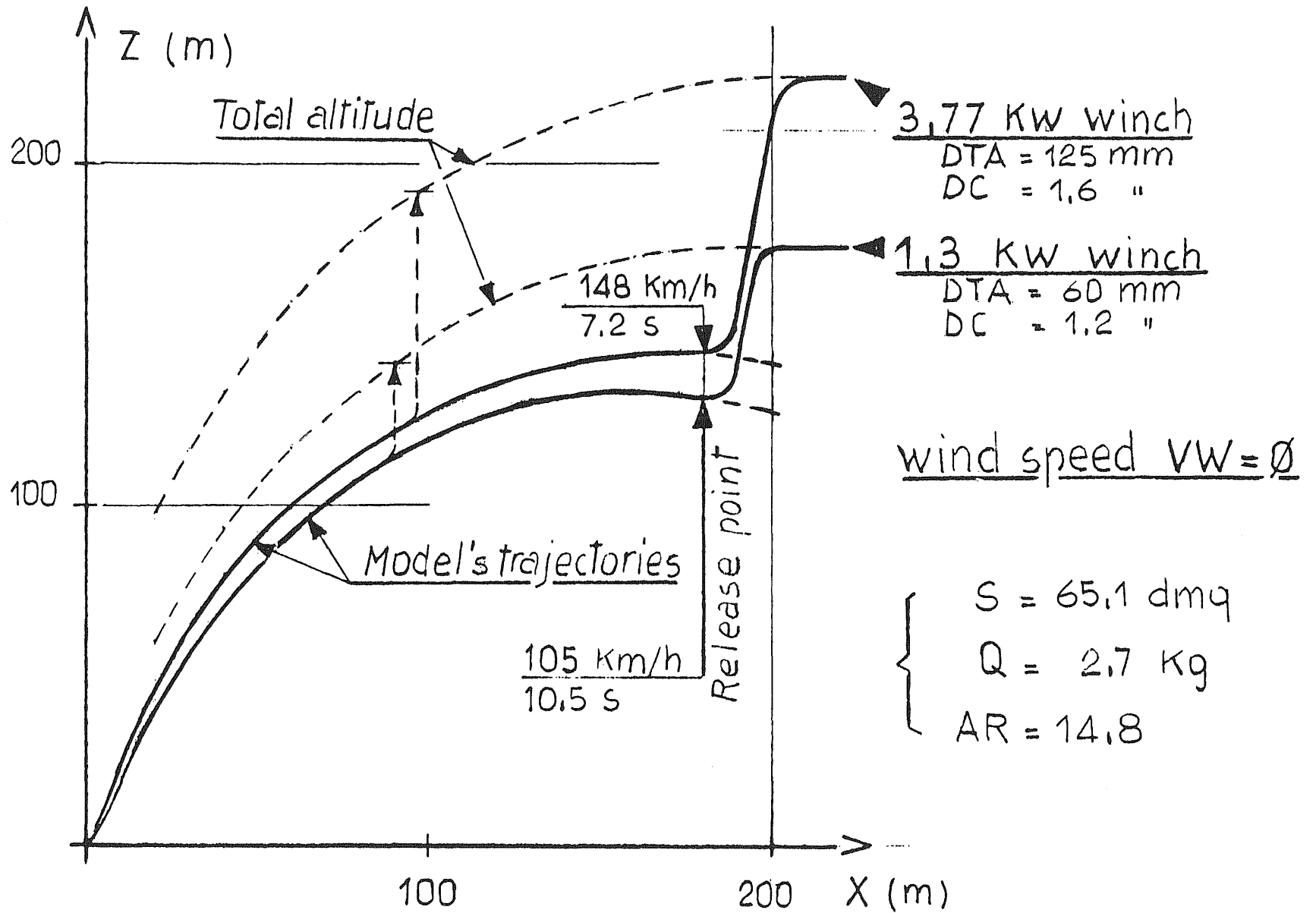
The complete listing of the program is not introduced in the paper for space reason. However, it is available from the Authors at the Symposium site.

8.0 REFERENCES

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2. " La resistenza del mezzo ", M. Panetti, Meccanica Applicata vol. 2, Levrotto & Bella.
3. " Drag Awareness ", Oran W.Nicks : Soaring ,Feb.1984
4. " HQ 2.5/9 airfoil characteristics ". Modellwindkanal-Stuttgart, 1983.

9.0 SYMBOLS

A	angle of the true airspeed and the horizontal line
A1	angle of the indicated airspeed and the horizontal line
AC	tangential acceleration
ACX	horizontal component of AC
ACZ	vertical component of AC
B	angle of the straight line (from the return pulley toward the towhook) and the horizontal line
C	torque of the winch motor
CD	drag coefficient
CL	lift coefficient
DC	towline wire diameter
DM	vertical space interval
DTA	winch drum diameter
DS	space interval
DT	time interval
DX	horizontal space interval
DZ	vertical space interval
FC	centrifugal force
FCX	horizontal component of FC
FCZ	vertical component of FC
I	inertia force (tangential)
IX	horizontal component of I
IZ	vertical component of I
K5	parameter of electric motor
K6	parameter of electric motor
L	distance of the model from the return pulley
P	lift
PD	power of winch motor
PX	horizontal component of P
PZ	vertical component of P
Q	model's weight
R	drag
RC	towline drag
RCX	horizontal component of RC
RCZ	vertical component of RC
RX	horizontal component of R
RZ	vertical component of R
TR	towline's traction
TRV	vertical component of TR (at the return pulley)
TRX	horizontal component of TR (at the return pulley)
V	speed at the end of the interval
VA	towline winding speed
VE	speed (end of interval)
VM	vertical speed (average)
VMI	indicated airspeed (average)
VMT	true airspeed (average)
VS	speed (beginning of interval)
VW	wind speed
VX	horizontal component of true airspeed
VZ	vertical component of true airspeed
X	horizontal distance of model from release point
Z	model's altitude (referred to ground)



```

1990 REM   SUBROUTINE FOR CALCULATION BY INTERVALS
2000 REM
2010 SA=DZ/SQR(DX^2 +DZ^2): SA1=DZ/SQR((DX-VW*DT)^2+DZ^2)
2020 CA =DX /SQR (DX^2+DZ^2): CA1=(DX-VW*DT)/SQR((DX-VW*DT)^2+DZ^2)
2030 L=SQR (Z^2+(LC-X)^2)
2040 VMI=SQR (((DX/DT)-VW)^2+(DZ/DT)^2)
2050 VMT=SQR((DX/DT)^2+(DZ/DT)^2)
2060 SB=Z/SQR(Z^2+(LC-X)^2)
2070 CB=(LC-X)/SQR(Z^2+(LC-X)^2)
2080 VA=VMT*(CA*CB-SA*SB)
2090 ACX=2*(DX-VS*DT*CA)/DT^2
2100 ACZ=2*(DZ-VS*DT*SA)/DT^2
2110 V=VS+(SQR(ACX^2+ACZ^2))*DT
2120 IX=-Q*ACX/9.810001
2130 IZ=-Q*ACZ/9.810001
2140 FCX=-((Q/9.810001)*(VMT^2)/L)*CB
2150 FCZ=((Q/9.810001)*(VMT^2)/L)*SB
2160 P=CL*S*(VMI^2)/1600
2170 GOSUB 2570
2180 CR=(K2*CDO)+((CL^2)/(K1*3.14*AR))
2190 R=(CR*S*VMI^2)/1600
2200 PX=-P*SA1
2210 PZ=P*CA1
2220 RX=-R*CA1
2230 RZ=-R*SA1
2240 SBA1=SA1*CB+CA1*SB
2250 RC=(CRC*DC*L*((VMI*SBA1)^2))/1000/48
2260 RCX=-RC*SB
2270 RCZ=-RC*CB
2280 REM   INPUT MAX RELEASE TRACTION
2290 IF X1>0 THEN 2320
2300 TR=TRS
2310 GOTO 2360
2320 IF PD<>0 THEN 2350
2330 TR=(.204-3900*VA/(DTA*K6))*K5*1000*FRP/DTA
2340 GOTO 2360
2350 TR=PD*102*FRP/VA
2360 TX =TR*CB
2370 TZ=-TR*SB
2380 FX = IX+FCX+PX+RX+TX+RCX
2390 FZ=-Q+IZ+FCZ+PZ+RZ+TZ+RCZ
2400 RETURN

```

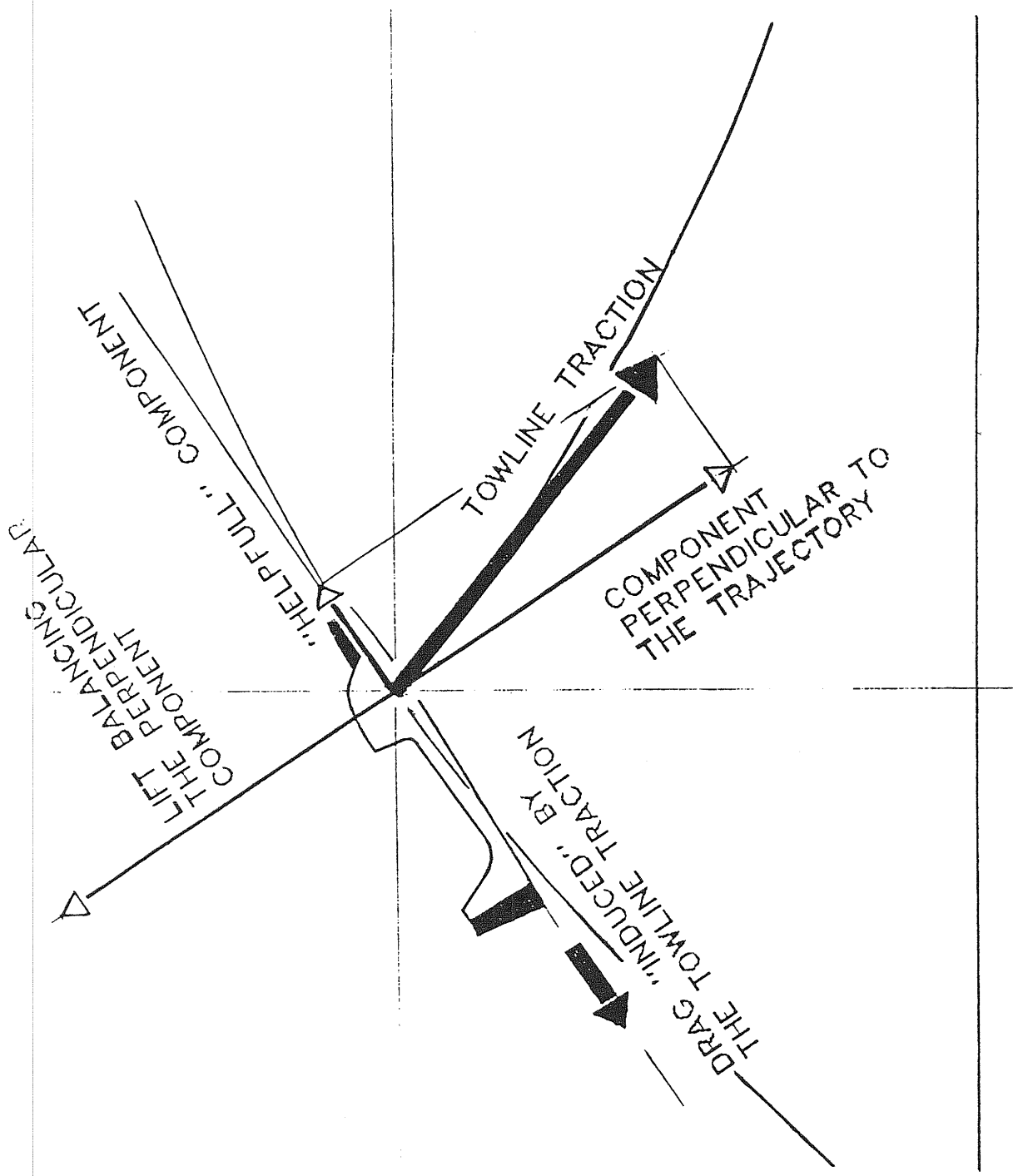
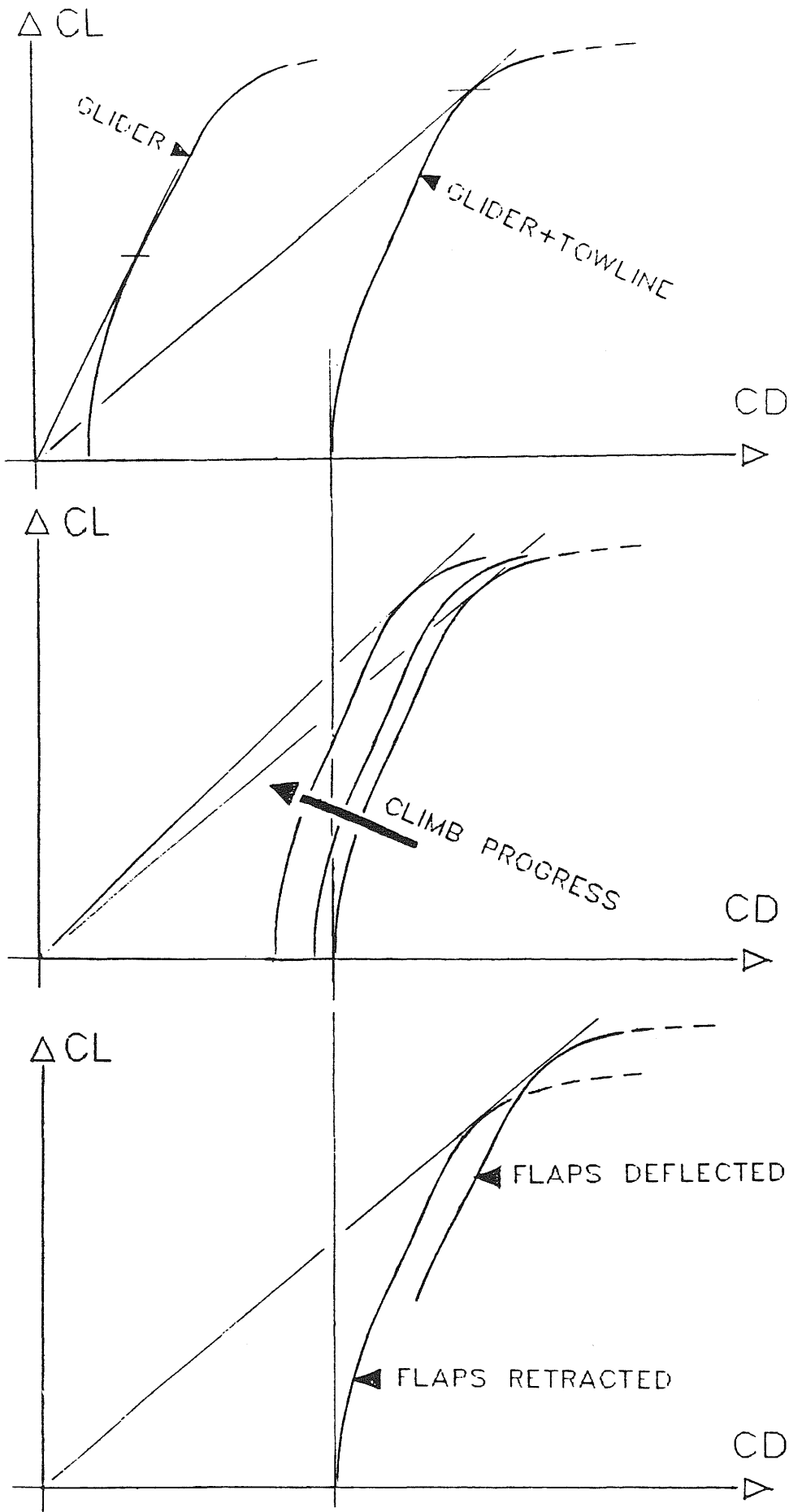


Fig 2



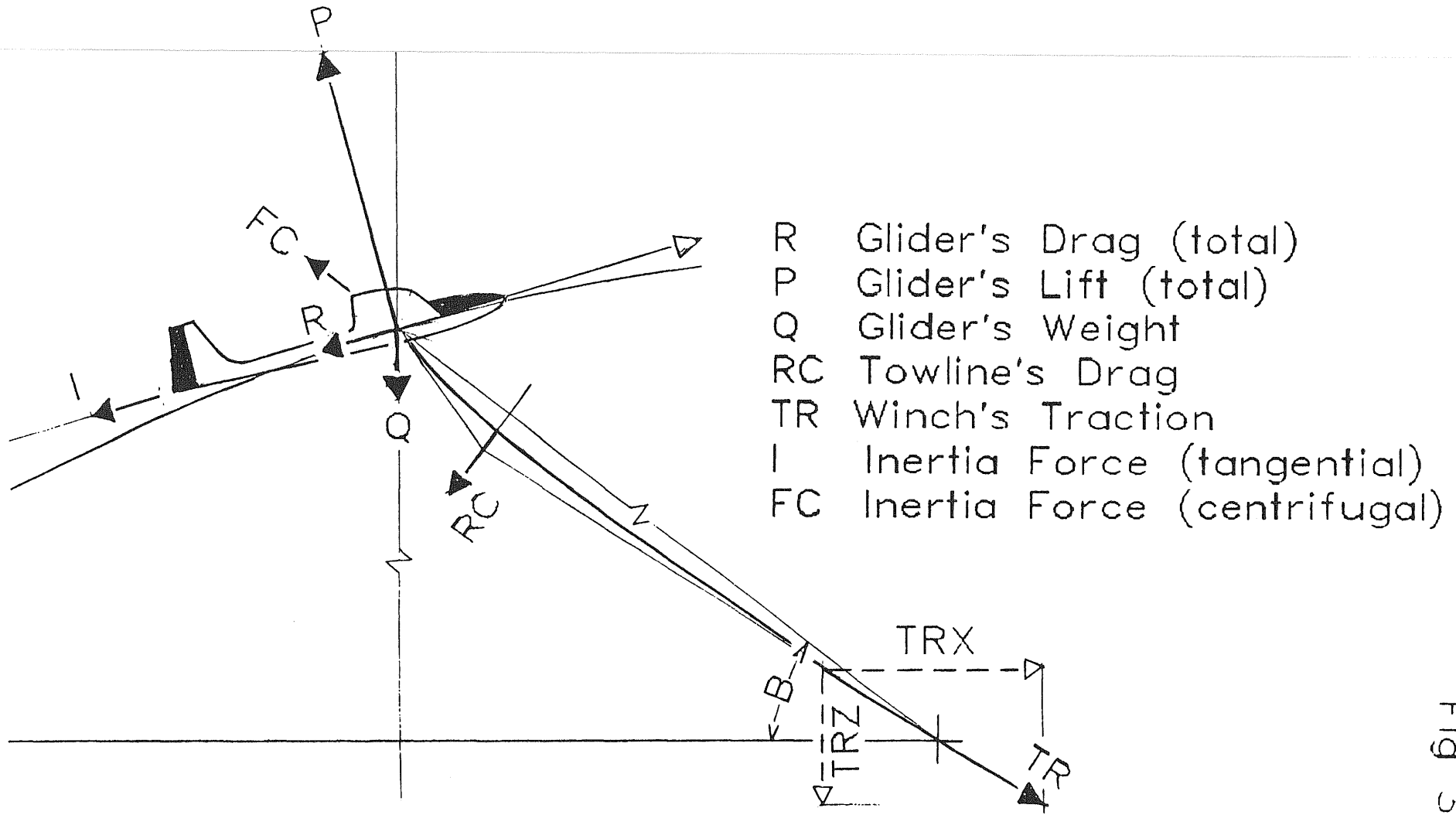


Fig 3

$$VX = DX / DT$$

$$VZ = DZ / DT$$

$$VMT = \text{SQR}(VX^2 + VZ^2)$$

$$SA = DZ / \text{SQR}(DX^2 + DZ^2)$$

$$CA = DX / \text{SQR}(DX^2 + DZ^2)$$

(S=sin)
(C=cos)

$$VA = VMT * C(A+B) =$$

$$= VMT * (CA * CB - SA * SB)$$

(S=sin)
(C=cos)

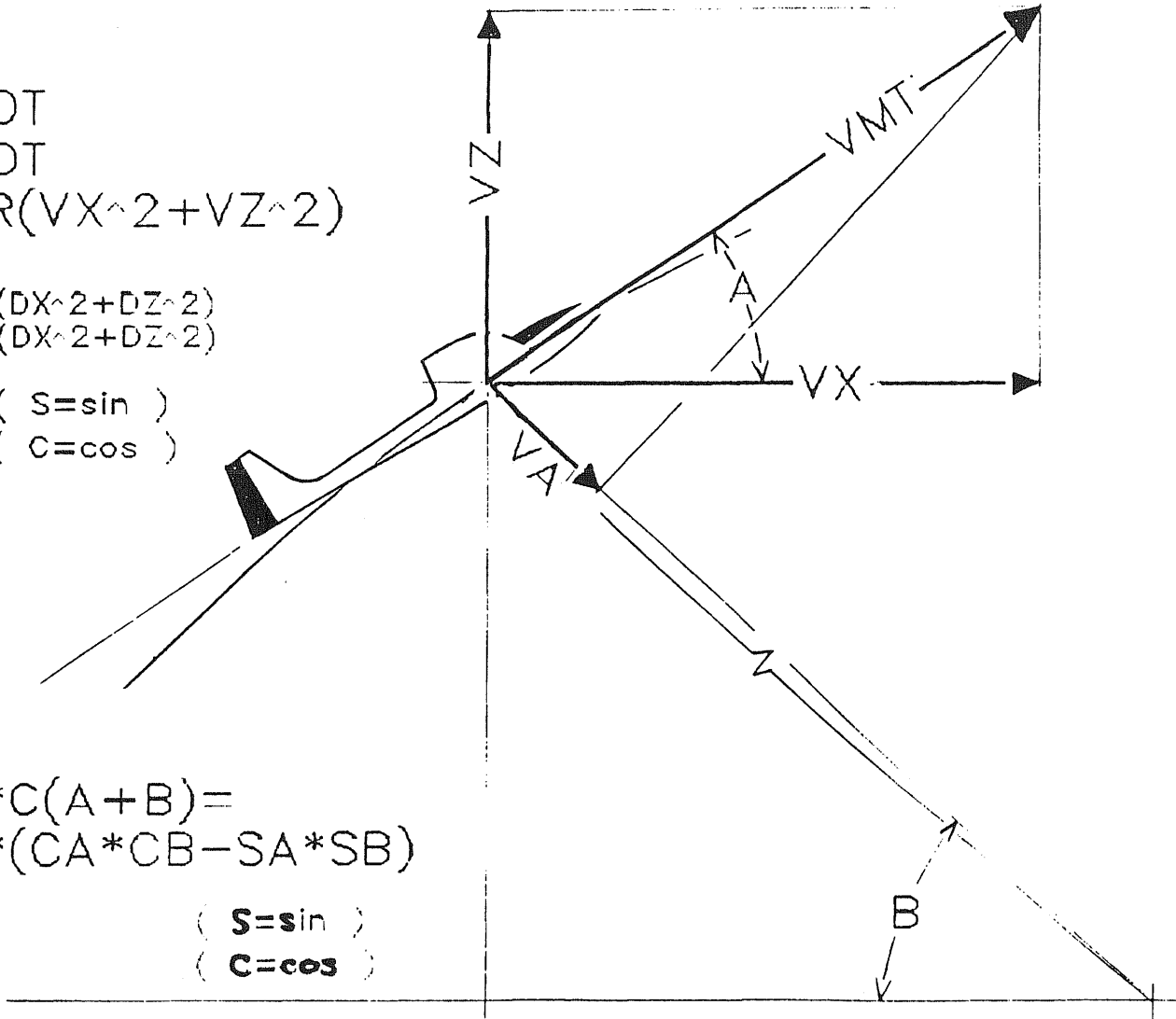
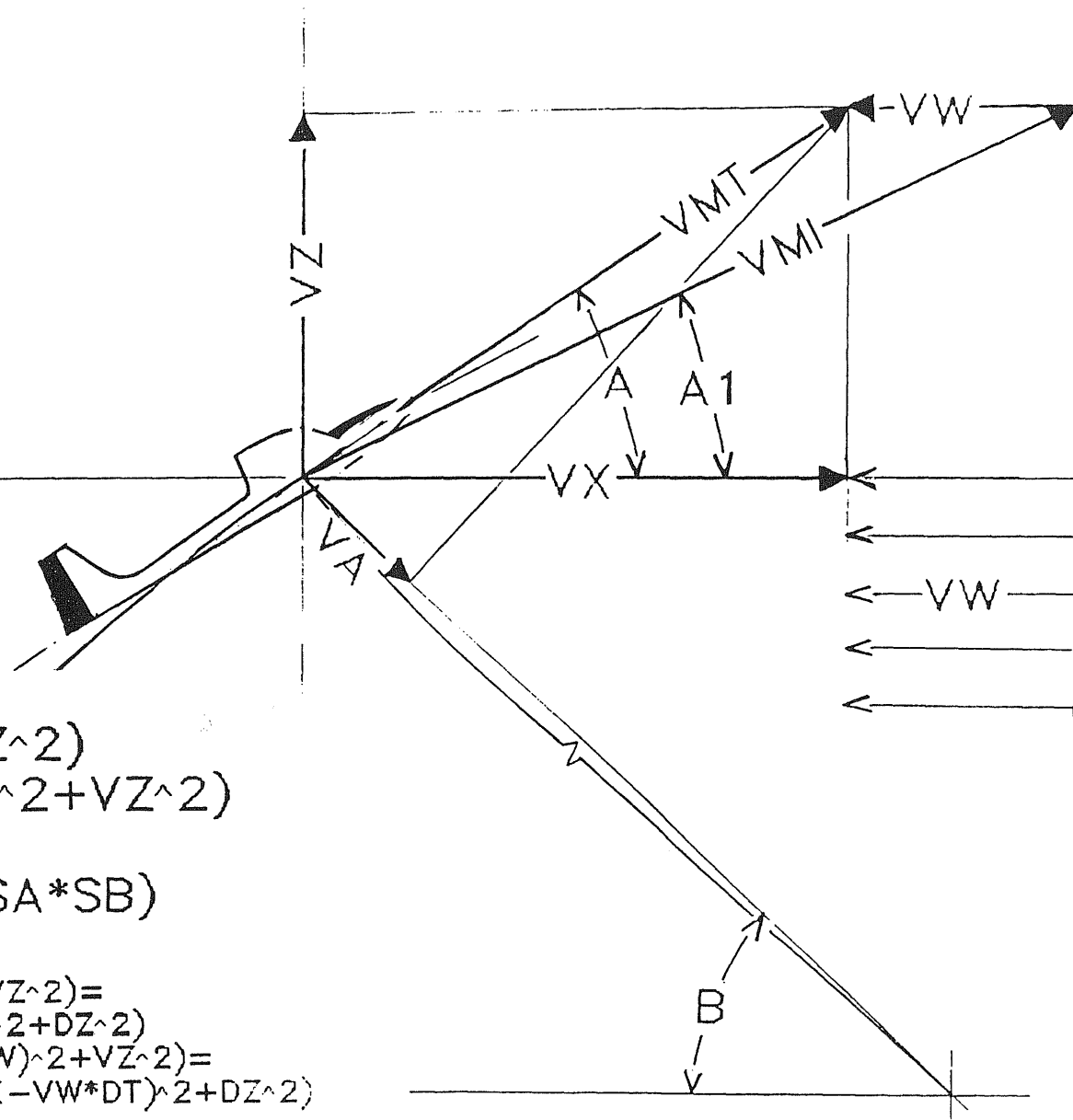
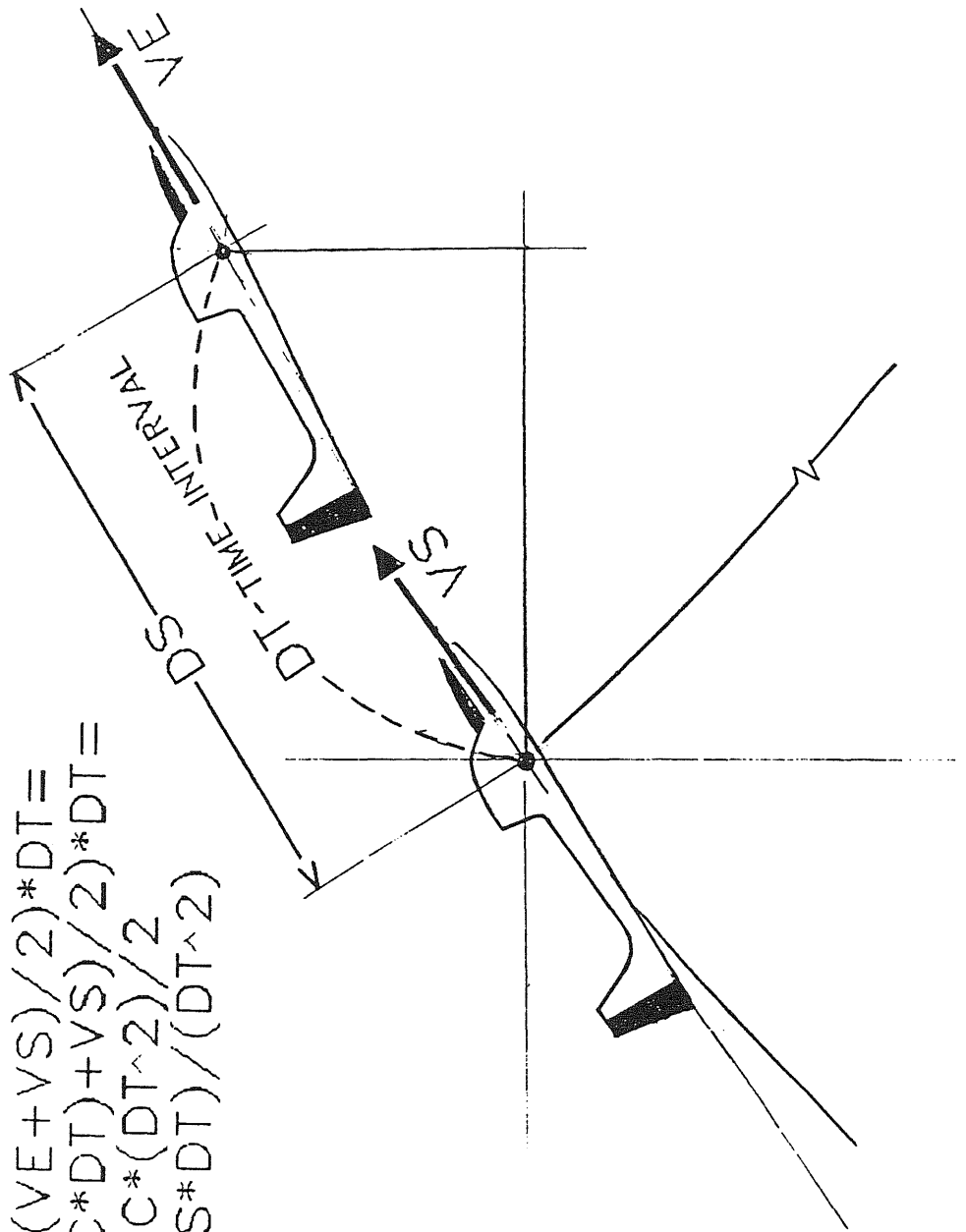


Fig 5

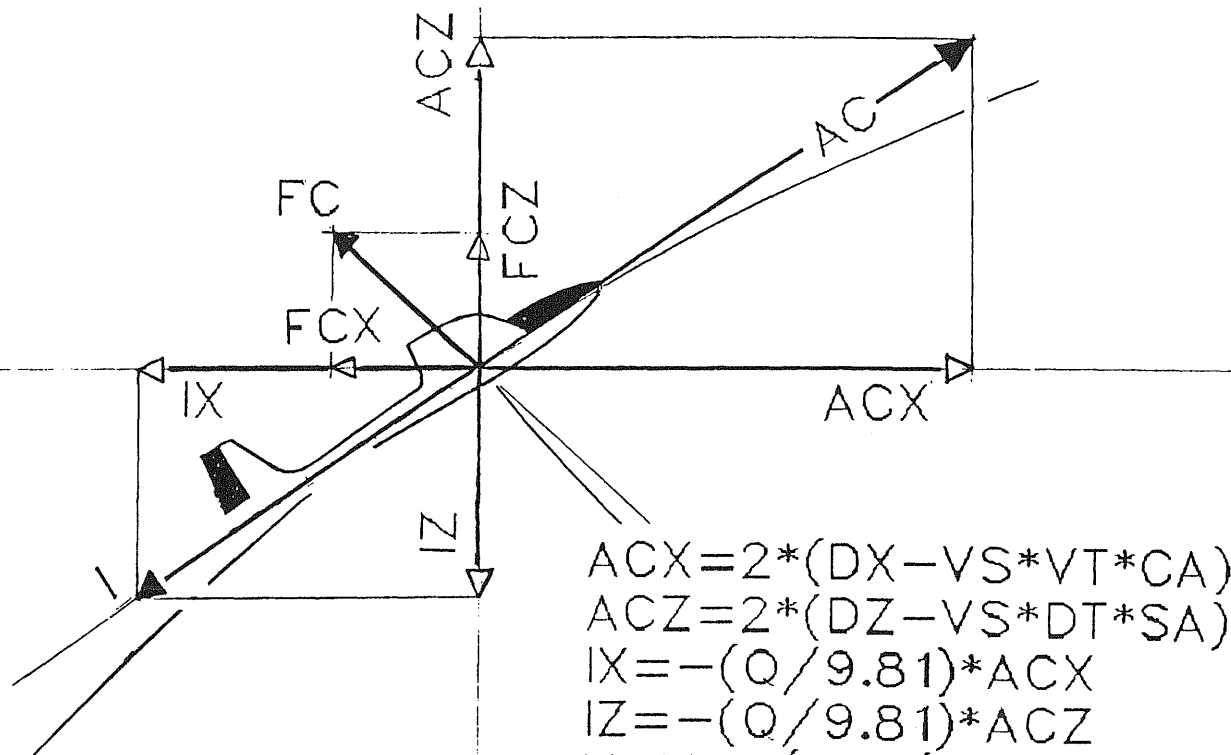


$$\begin{aligned}
 VX &= DX / DT \\
 VZ &= DZ / DT \\
 VMT &= \text{SQR}(VX^2 + VZ^2) \\
 VMI &= \text{SQR}((VX - VW)^2 + VZ^2) \\
 VA &= VMT * C(A + B) = \\
 &= VMT * (CA * CB - SA * SB) \\
 \\
 SA1 &= VZ / \text{SQR}((VX - VW)^2 + VZ^2) = \\
 &= DZ / \text{SQR}((DX - VW * DT)^2 + DZ^2) \\
 CA1 &= (VX - VW) / \text{SQR}((VX - VW)^2 + VZ^2) = \\
 &= (DX - VW * DT) / \text{SQR}((DX - VW * DT)^2 + DZ^2) \\
 \\
 & (S = \sin) \\
 & (C = \cos)
 \end{aligned}$$

Fig 6



$$\begin{aligned}
 DS &= VM * DT = ((VE + VS) / 2) * DT = \\
 &= (((VS + AC * DT) + VS) / 2) * DT = \\
 &= VS * DT + AC * (DT^2) / 2 \\
 AC &= 2 * (DS - VS * DT) / (DT^2)
 \end{aligned}$$



$$ACX = 2 * (DX - VS * VT * CA) / (DT^2)$$

$$ACZ = 2 * (DZ - VS * DT * SA) / (DT^2)$$

$$IX = -(Q / 9.81) * ACX \quad (S = \sin)$$

$$IZ = -(Q / 9.81) * ACZ \quad (C = \cos)$$

$$V = VS + (SQR(ACX^2 + ACZ^2)) * DT$$

$$FC = (Q / 9.81) * (VMT^2) / L$$

$$FCX = -((Q / 9.81) * (VMT^2) / L) * CB$$

$$FCZ = ((Q / 9.81) * (VMT^2) / L) * SB$$

(S = sin)
(C = cos)

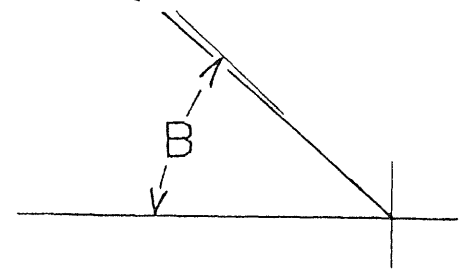
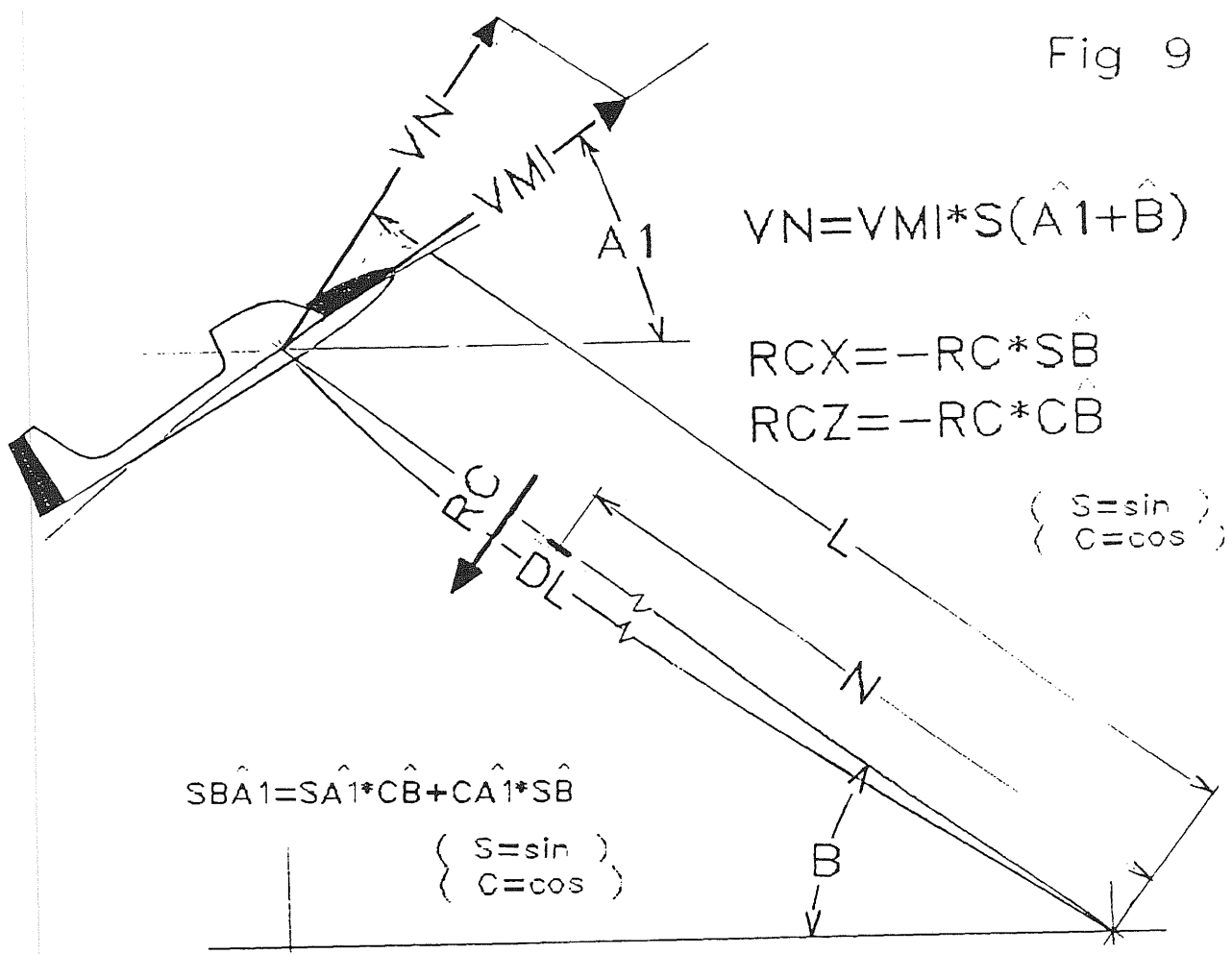


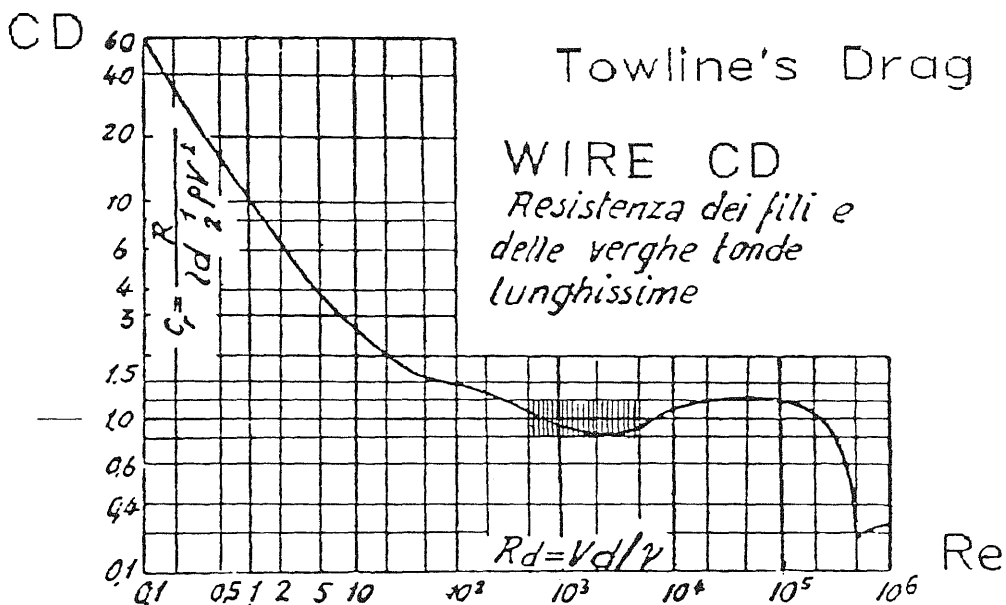
Fig 8

Fig 9



$$RC = \int_0^L CRC * DC * DL * (VN * N / L)^2 / 16 =$$

$$= CRC * DC * L * ((VMI * S\hat{B}\hat{A1})^2) / 48$$



$$P = CL * S * (VM^2) / 16$$

$$R = CD * S * (VM^2) / 16$$

$$PX = -P * CA1$$

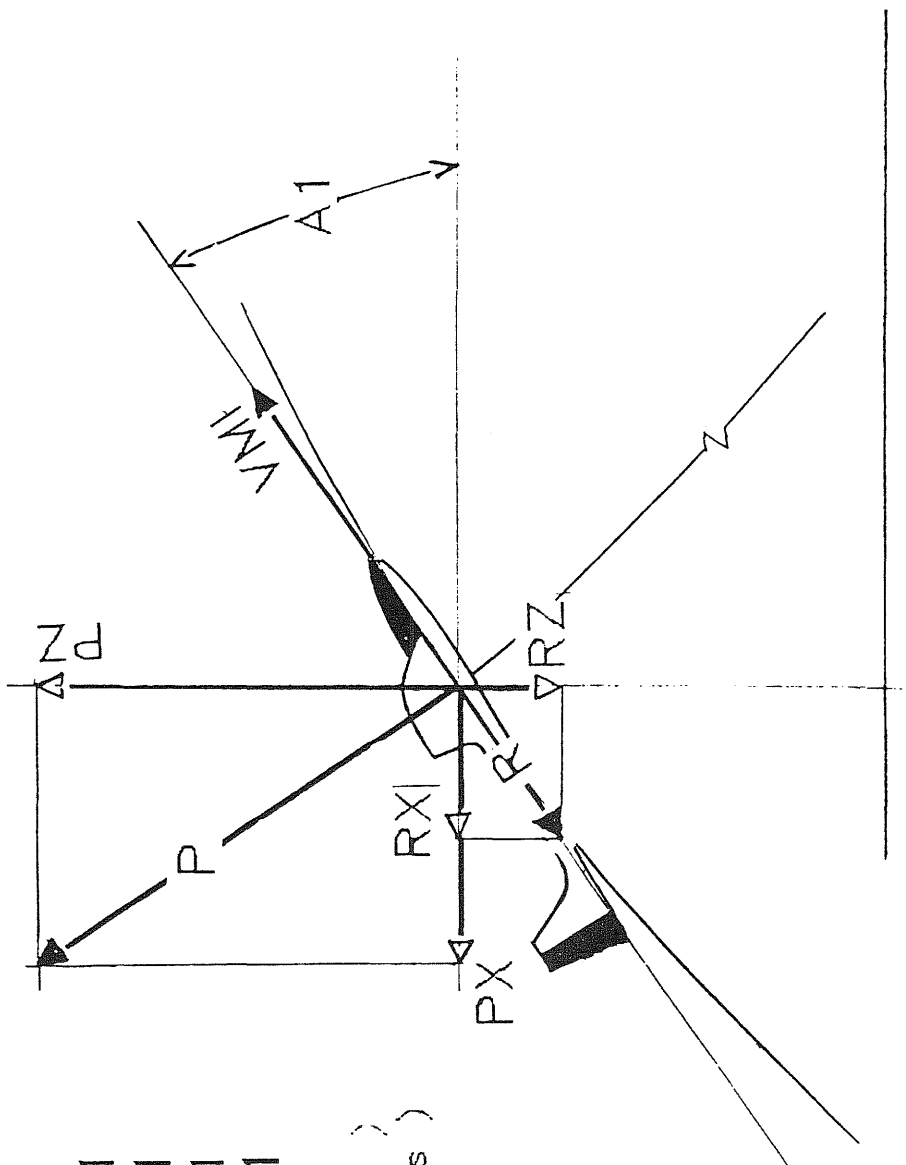
$$PZ = P * SA1$$

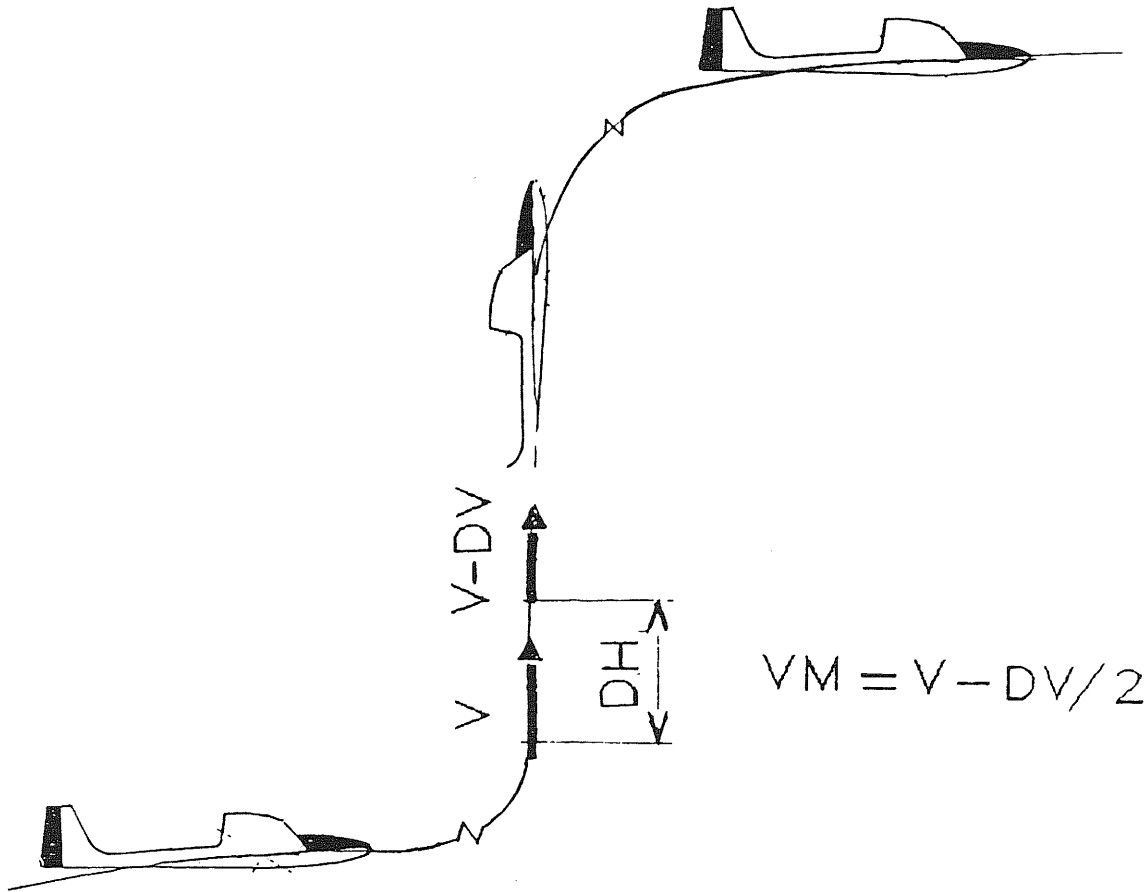
$$RX = -R * SA1$$

$$RZ = -R * CA1$$

$$(S = \sin)$$

$$(C = \cos)$$





$$(V^2 - (V - DV)^2) * Q / (2 * 9.81) = Q * DH + R * DH$$

$$R = CD * S * (VM^2) / 16$$

$$DV = 1$$

$$DH = ((2 * V - 1) / 2 * 9.81) / (1 + R / Q)$$

$$R = CD * S * ((V - 0.5)^2) / 16$$

```

10 CLS
20 PRINT " MODEL SAILPLANES TOWING PROGRAM ( TRAINO 13 ) "
30 PRINT " V. & L. DE FILIPPIS ( ISSUE 1/91 ) "
40 REM ++++++
50 REM CHARACTERISTICS OF THE MODEL,WINCH SYSTEM AND ENVIRONMENT
60 REM+++++
70 PRINT "CHARACTERISTICS OF THE MODEL"
80 PRINT "-----"
90 INPUT "WEIGHT (kg) ";QN
100 PRINT TAB(40);" QN = ";QN;"kg"
110 INPUT "BALLAST WEIGHT (kg) ";QZ
120 PRINT TAB(40);" QZ = ";QZ;"kg"
130 INPUT "WING SURFACE (dmq)";S
140 PRINT TAB(40); " S = ";S; "dmq"
150 INPUT "TOWING MAX CL";CLM
160 PRINT TAB(40);"CLM = ";CLM
170 INPUT "WING SHAPE CORRECTIVE COEFFICIENT";K1
180 PRINT TAB(40); " K1 = ";K1
190 INPUT "ADDITIONAL DRAGS COEFFICIENT";K2
200 PRINT TAB(40); " K2 = ";K2
210 INPUT "ASPECT RATIO";AR
220 PRINT TAB(40); " AR = ";AR
230 PRINT
240 PRINT "CHARACTERISTICS OF THE WINCH SYSTEM"
250 PRINT "-----"
260 INPUT "MOTOR MAX POWER (kW)" ;PD
270 PRINT TAB(40);" PD = ";PD;"kW"
280 INPUT "ELECTRIC MOTOR PARAMETER K5 (Nm)";K5
290 PRINT TAB(40);" K5 = ";K5;"Nm"
300 INPUT "ELECTRIC MOTOR PARAMETER K6 (giri/1')";K6
310 PRINT TAB(40);" K6 = ";K6;"giri/1'"
320 INPUT "POWER REDUCTION COEFFICIENT";FRP
330 PRINT TAB(40);"FRP = ";FRP
340 INPUT "DRUM DIAMETER (mm)";DTA
350 PRINT TAB(40);"DTA = ";DTA;"mm"
360 INPUT "TOWLINE LENGTH (m)";LC
370 PRINT TAB(40);" LC = ";LC; "m"
380 INPUT "WIRE DIAMETER (mm) ";DC
390 PRINT TAB(40);" DC = ";DC; "mm"
400 INPUT "WIRE CD ";CRC
410 PRINT TAB(40);"CRC = ";CRC
420 INPUT "MAX ALLOWED TRACTION (kg)";TRM
430 PRINT TAB(40);"TRM = ";TRM;"kg"
440 PRINT
450 PRINT "ENVIRONMENT DATA "
460 PRINT "-----"
470 INPUT "WIND SPEED (m/s) " ;VW
480 REM NEGATIVE VALUE IF WIND IS OPPOSITE TO TOWING DIRECTION
490 PRINT TAB(40);" VW = ";VW;"m/s"
500 PRINT
510 PRINT "COMPUTING DATA "
520 PRINT "-----"
530 INPUT "TIME INTERVAL INCREMENT (s)
      .1(no wind)/.05(wind) ";DDT
540 PRINT TAB(40);"DDT = ";DDT;"s"
550 INPUT "INITIAL TIME INTERVAL INCREMENT (s)
      .03(no wind)/.01(wind) ";DTI
560 PRINT TAB(40);"DTI = ";DTI;"s"
570 PRINT
580 REM ++++++
590 REM CALCULATION OF THE CLIMB DURING TOWING AND AFTER THE LINE IS RELEAS
600 REM ++++++
610 PRINT "CLIMB DATA"

```

```

620 PRINT "-----"
630 INPUT "MAX RELEASE TENSION (kg)";TRS
640 PRINT TAB(40);"TRS = ";TRS;"kg"
650 INPUT "SPEED AT THE CLIMB END (m/s)";VR
660 PRINT TAB(40);" VR = ";VR;"m/s"
670 IN$=INKEY$:IF IN$="" THEN 670
680 REM ++++++
690 REM INCREMENTS AND APPROXIMATIONS
700 REM
710 REM HORIZONTAL DISTANCE INCREMENT : DX ( m )
720 REM ALTITUDE INCREMENT : DZI ( m )
730 REM FORCE APPROXIMATION : DF ( kg )
740 REM CL INCREMENT : DCL
750 DX=2: DZI=.5: DF=.1: DCL=.01
760 REM ++++++
770 REM INITIATION DATA
780 T=0: X1 =0: Z1 = 2: V1=0: CL1=CLM
790 REM ++++++
800 REM RESULTS FORMAT
810 REM
820 LPRINT " T X Z CL V VA TR H "
830 PRINT
840 LPRINT " s m m m/s m/s kg m "
850 PRINT
860 PRINT
870 REM ++++++
880 REM CLIMB CHARACTERISTICS ( CL FOR MAX CLIMBING )
890 REM ++++++
900 CL=CL1: VS=V1: X=X1: Z=Z1: Q=QN+QZ
910 GOSUB 1350
920 REM ++++++
930 REM REDUCTION OF CL FOR KEEPING TR<TRM
940 REM
950 IF TR<TRM THEN 980
960 CL1=CL-DCL
970 GOTO 900
980 Z=Z+DZ
990 REM ++++++
1000 REM ALTITUDE GAIN BY REDUCING THE SPEED
1010 REM
1020 GOSUB 2440
1030 H=Z+HR
1040 REM ++++++
+
1050 REM CALCULATION OF CL FOR REACHING MAX ALTITUDE
1060 A=H
1070 CL=CL-DCL
1080 Z=Z1
1090 GOSUB 1350
1100 Z=Z+DZ
1110 GOSUB 2440
1120 H=Z+HR
1130 B=H
1140 IF B-A<=0 THEN 1170
1150 A=B
1160 GOTO 1070
1170 CL=CL+DCL: Z=Z1
1180 GOSUB 1350
1190 T=T+DT: X=X+DX: Z=Z+DZ
1200 T1=T: X1=X: Z1=Z: CL1=CL: V1=V
1210 GOSUB 2440
1220 H=Z+HR
1230 REM ++++++

```

```

1240 REM PRINT OF RESULTS
1250 REM
1260 LPRINT USING "   ##.##   ##.##   ##.##   #.##   ##.##   ##.##   ##.##
#.##";T1,X1,Z1,CL1,V1,VA,TR,H
1270 PRINT
1280 REM ++++++
1290 REM CALCULATION OF SUBSEQUENT POSITIONS
1300 IF X<LC THEN 900
1310 END
1320 REM ++++++
1330 REM CALCULATION OF DZ ( FZ=0 FOR GIVEN DT )
1340 REM
1350 K3=0
1360 DZ=0
1370 GOSUB 1750
1380 PRINT" * "
1390 CLS
1400 GOSUB 2010
1410 ZC=FZ
1420 PRINT" * "
1430 IF ABS(ZC)>DF THEN 1450
1440 RETURN
1450 IF ZC>0 THEN 1480
1460 IF ZC<0 THEN 1600
1470 K3=K3+1
1480 DZ=DZ+DZI/(2^K3)
1490 IF DZ>=DX*(LC-X1)/Z1 THEN 1600
1500 GOSUB 1750
1510 PRINT" * "
1520 CLS
1530 GOSUB 2010
1540 ZC=FZ
1550 PRINT" * "
1560 IF ABS(ZC)>DF THEN 1580
1570 RETURN
1580 IF ZC>0 THEN 1480
1590 K3=K3+1
1600 DZ=DZ-DZI/(2^K3)
1610 IF DZ>=DX*(LC-X1)/Z1 THEN 1480
1620 GOSUB 1750
1630 PRINT" * "
1640 CLS
1650 GOSUB 2010
1660 ZC=FZ
1670 PRINT" * "
1680 IF ABS(ZC)>DF THEN 1700
1690 RETURN
1700 IF ZC>0 THEN 1470
1710 IF ZC<0 THEN 1600
1720 REM ++++++
1730 REM CALCULATION OF DT ( FX=0 FOR GIVEN DZ )
1740 REM
1750 DT=DTI
1760 GOSUB 2010
1770 XA=FX
1780 IF ABS(XA)>DF GOTO 1800
1790 RETURN
1800 K4=0
1810 DT=DT+DDT/(2^K4)
1820 GOSUB 2010
1830 XB=FX
1840 IF ABS(XB)>DF THEN 1860
1850 RETURN

```

```

1860 IF SGN(XA)=SGN(XB) THEN 1810
1870 K4= K4+1
1880 DT=DT-DDT/(2^K4)
1890 GOTO 1920
1900 K4=K4+1
1910 DT=DT+DDT/(2^K4)
1920 GOSUB 2010
1930 XB =FX
1940 IF ABS(XB)>DF THEN 1960
1950 RETURN
1960 IF SGN(XB)=SGN(XA) THEN 1900
1970 IF SGN(XB)<>SGN(XA) THEN 1870
1980 REM ++++++
1990 REM SUBROUTINE FOR CALCULATION BY INTERVALS
2000 REM
2010 SA=DZ/SQR(DX^2 +DZ^2): SA1=DZ/SQR((DX-VW*DT)^2+DZ^2)
2020 CA =DX /SQR (DX^2+DZ^2): CA1=(DX-VW*DT)/SQR((DX-VW*DT)^2+DZ^2)
2030 L=SQR (Z^2+(LC-X)^2)
2040 VMI=SQR (((DX/DT)-VW)^2+(DZ/DT)^2)
2050 VMT=SQR((DX/DT)^2+(DZ/DT)^2)
2060 SB=Z/SQR(Z^2+(LC-X)^2)
2070 CB=(LC-X)/SQR(Z^2+(LC-X)^2)
2080 VA=VMT*(CA*CB-SA*SB)
2090 ACX=2*(DX-VS*DT*CA)/DT^2
2100 ACZ=2*(DZ-VS*DT*SA)/DT^2
2110 V=VS+(SQR(ACX^2+ACZ^2))*DT
2120 IX=-Q*ACX/9.810001
2130 IZ=-Q*ACZ/9.810001
2140 FCX=-((Q/9.810001)*(VMT^2)/L)*CB
2150 FCZ=((Q/9.810001)*(VMT^2)/L)*SB
2160 P=CL*S*(VMI^2)/1600
2170 GOSUB 2570
2180 CR=(K2*CDO)+((CL^2)/(K1*3.14*AR))
2190 R=(CR*S*VMI^2)/1600
2200 PX=-P*SA1
2210 PZ=P*CA1
2220 RX=-R*CA1
2230 RZ=-R*SA1
2240 SBA1=SA1*CB+CA1*SB
2250 RC=(CRC*DC*L*((VMI*SBA1)^2))/1000/48
2260 RCX=-RC*SB
2270 RCZ=-RC*CB
2280 REM INPUT MAX RELEASE TRACTION
2290 IF X1>0 THEN 2320
2300 TR=TRS
2310 GOTO 2360
2320 IF PD<>0 THEN 2350
2330 TR=(.204-3900*VA/(DTA*K6))*K5*1000*FRP/DTA
2340 GOTO 2360
2350 TR=PD*102*FRP/VA
2360 TX =TR*CB
2370 TZ=-TR*SB
2380 FX = IX+FCX+PX+RX+TX+RCX
2390 FZ=-Q+IZ+FCZ+PZ+RZ+TZ+RCZ
2400 RETURN
2410 REM ++++++
2420 REM VERTICAL CLIMB AFTER THE TOWLINE IS RELEASED
2430 REM
2440 V=V
2450 HR =0
2460 GOSUB 2600
2470 GOTO 2490
2480 V=UR-1

```

```

2490 DH=(2*V-1)/((1+((CDO*S/100)/(16*Q))*(V-.5)^2)*19.62)
2500 HR=HR+DH
2510 UR=V
2520 IF UR>=VR THEN 2480
2530 RETURN
2540 REM ++++++
2550 REM TABLE CL/CDO FOR SECTION HQ 2.5/9 RE = 200.000
2560 REM
2570 IF CL <=1 THEN 2600
2580 IF CL<=1.15 THEN 2620
2590 IF CL<= 1.2 THEN 2640
2600 CDO = .01
2610 RETURN
2620 CDO =.01 + 14*(CL-1)/150
2630 RETURN
2640 CDO = .024 +.016 *(CL -1.15)/.05
2650 RETURN

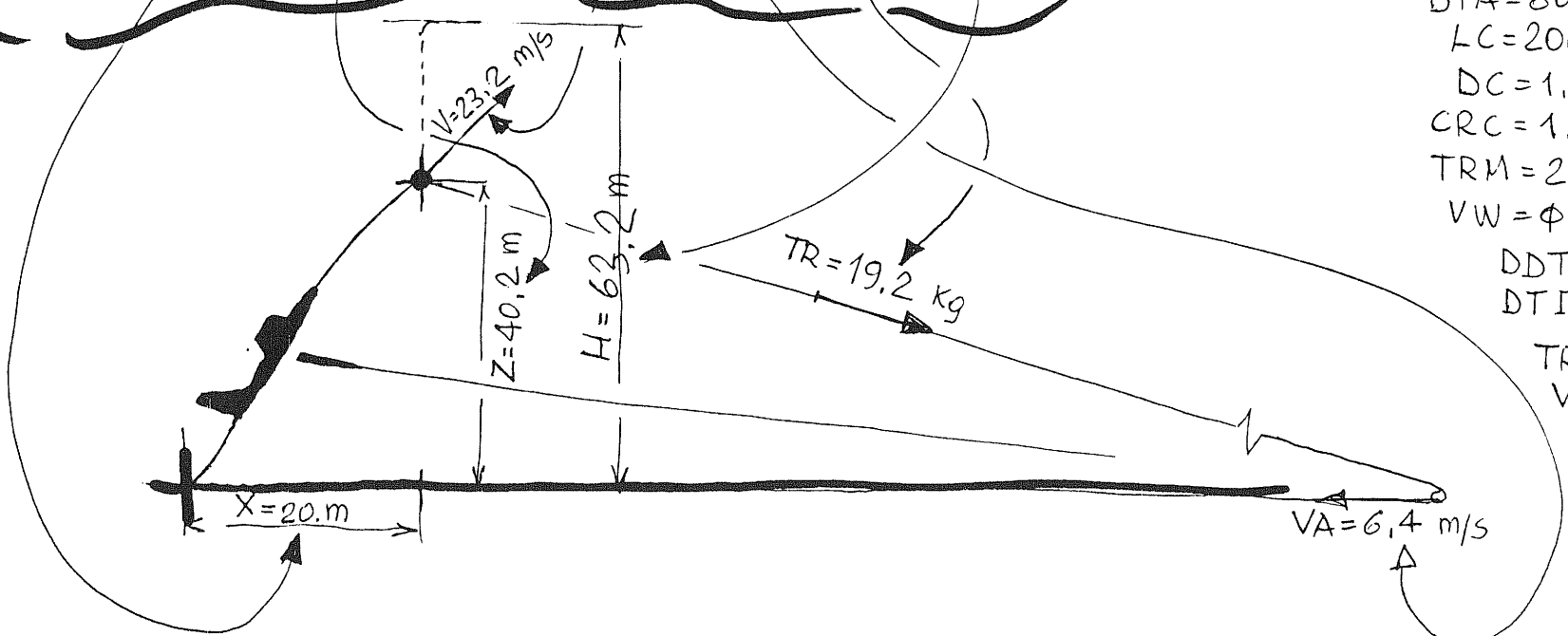
```

Note: As long as the program is running, an asterisk* in the front of the screen is blinking. If it stops to blink, the program is stopped by some inconsistent value.

Printing sample

T	X	Z	CL	V	VA	TR	H
s	m	m		m/s	m/s	kg	m
0.25	2.0	2.0	1.10	16.3	8.1	15.0	11.8
0.46	4.0	5.2	1.09	18.8	9.2	11.6	18.8
0.69	6.0	9.3	1.09	20.5	8.2	14.2	26.3
0.93	8.0	13.9	1.09	21.6	7.4	16.4	33.1
1.17	10.0	18.7	1.09	22.3	6.9	17.7	39.6
1.40	12.0	23.5	1.09	22.7	6.7	18.5	44.9
1.61	14.0	28.0	1.07	22.9	6.6	18.6	49.7
1.82	16.0	32.3	1.07	23.1	6.5	19.0	55.1
2.02	18.0	36.4	1.07	23.2	6.4	19.1	59.3
2.20	20.0	40.2	1.07	23.2	6.4	19.2	63.2

QN = 2,2
 QZ = ϕ
 S = 54
 CLM = 1,1
 K1 = 0,95
 K2 = 1,25
 AR = 14
 PD = ϕ
 K5 = 16
 K6 = 3200
 FRP = 0,9
 DTA = 80
 LC = 200
 DC = 1,2
 CRC = 1,
 TRM = 25
 VW = ϕ
 DDT = ,1
 DTI = ,03
 TRS = 15
 VR = 10



TWO PC PROGRAMS FOR THE STRUCTURAL DESIGN OF MODEL WINGS

by Steve Pituch
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These two programs can help the model designer produce stronger and lighter wing spars. The first program that I will describe is called the Wing Shear-Moment program, or WSM for short. It gives the designer the moments and shears in a wing at every rib location, and this information can be used to design a tapered spar. The second program is called the Composite Beam Analysis program, or CBA for short. It gives the designer the stresses in a simple or composite wing spar. Conversely, if you give the program the allowable stresses of all the spar components, the program will tell you the maximum allowable load that the spar can withstand, and also which component of the spar is critically stressed. The best way to use these programs is to first enter the planform geometry and G factor into the WSM program, and then after you get the forces from the WSM program, design a spar to withstand these forces with the CBA program. The following examples will illustrate a typical design session.

Part I, Wing Shear Moment Program

Refer to the Example 1 output from the WSM program. When you enter "WSM" at the DOS prompt the screen will show a wing layout similar to the boxed in diagram, but without any actual numbers. The root chord is at the left side, and the tip chord is at the right side. The program also allows for a polyhedral break between the inner and outer wing panels. The diagram shows only one half of the wing. You will be asked for the basic dimensions describing the wing planform, and also the number of bays (areas between ribs) for the inner wing panel and the outer wing panel. You will then be asked for the dihedral angles for each panel, and the weight of the plane and the G factor that you want to design the wing for. I normally use a G factor that I want the wing to withstand and not suffer any structural damage. The output gives the vertical shear in pounds, and the bending moment in inch*pounds at every rib location. In Example 1 the spar would have to withstand a maximum moment of 78 inch*pounds at the center of the wing.

By running the program several times using different geometries, one can quickly realize how the moment will vary in different designs. The classic case is when you want to extend the span of an existing design. This program can help you determine how much additional reinforcing the center spar will need and how far that reinforcing should extend from the center of the wing. Another case would be when you want to design a tapered spar. If you were designing a hand launch glider and wanted to laminate 1/16 inch square spruce for a spar, and each piece of spruce could take 20 inch*pounds of moment, the Example 1 output would indicate that you would

need to double up on the spar section at the 11th rib from the tip, and triple up on the spar section at the 13th rib. Thus the program can help the designer produce lighter spars.

Also notice the Rolling Dihedral Moment Factor (RDMF for short) at the bottom of the output. This is probably of limited use to those who design aileron ships, but may be of interest to those of us that still design polyhedral sailplanes. The RDMF is simply the summation of the moments on the wing based on a unit horizontal load hitting the horizontally projected area of each bay. Since the horizontally projected area of the wing is proportional to the dihedral angle, the RDMF should give us a good idea of the relative ability of a wing design to turn an airplane. Also since it is based on the area of each bay, it should also take into account the varying geometry of a tapered wing.

In Example 2 for the WSM program the same geometry as Example 1 was used but the designer decided to use zero dihedral for the center section so that he could more easily build in flaps. But he also wanted the wing to have the same turning ability as the design in Example 1, which had 5 degrees dihedral for the center panels, and 10 degrees dihedral for the outer panels. That means that the new design must have more dihedral for the outer panels. When example 2 was run with 0 degrees dihedral for the center panels, and 15 degrees dihedral for outer panels, the resulting RDMF was 147.9 which is close to the Example 1 RDMF of 138.9. Both designs will probably have the same turning ability.

In Example 3 for the WSM program the same geometry was used again but the weight of the sailplane and the G factor was changed. To speed up the design cycle the program has the option of reusing the geometry and changing only either the loading or the dihedral angles.

Part II, Composite Beam Analysis Program

This program was written to provide a tool for designers who want to use different materials in wing spar layouts. How different materials share bending stresses when they are bonded together is a function of the ratio of the stiffnesses of the materials. The modulus of elasticity (E_s) describes the stiffness of a material, and is defined as stress/strain, which in layman's terms is the load on a material divided by the resulting unit deformation. The E_s of dry Sitka Spruce is 1570 Ksi (thousand pounds per square inch), according to the Wood handbook. If the E_s of a piece of carbon fiber that you wanted to use was 15,750 Ksi, then the carbon fiber would be 10 times stiffer than the spruce. If you wanted to bond the two materials together and use the resulting section as a spar, you must transform one of the materials into the equivalent amount of the other material, before the stresses can be found. If you had .1 square inches of carbon fiber and .3 square inches of spruce and wanted to combine them, you would multiply the area of the carbon fiber (.1) by the ratio of the stiffnesses (10) to get an equivalent area of spruce (1 square inch). You would then add this equivalent area to the

actual area of spruce (.3) to get a total area of 1.3 square inches of spruce. Therefore our composite section behaves just like a spar made of 1.3 square inches of spruce. This is the method that civil engineers use to combine concrete and steel when they design reinforced concrete beams, but it works with any combination of materials. The secret is using the correct values of Es. At this time I can only guess at the Es of the carbon fiber materials presently available to modelers. I have used .007 inch thick carbon fiber sheet stock where the carbon fiber is impregnated with resin and bonded to fiberglass cloth, and it does really stiffen up a spar, but until I get a better data I can only guess at the Es. If anyone has this information please write to Herk as this information would be a great help to modelers using this program.

At the DOS prompt enter "CBA" and a description of the program will appear on the screen along with a diagram similar to the one in Example 1 for the CBA program. The main flanges attach to the center web. The auxiliary flanges attach to the outside of main flanges. The auxiliary webs attach to the sides of the main flanges. Typically, the main flanges are wood, the auxiliary flanges are wood, carbon fiber or boron, and the auxiliary webs are aircraft plywood. Any material can be used for these components as long as you have a reasonable idea of what the Es is of each material. The program prompts you for all the required information, and when you enter the data it replaces the prompt with a statement containing the data. If you don't want to use a certain component simply enter zero for the dimension. From the input part of Example 1, it can be seen that the designer wants to check a simple beam with a 3/8 inch by 3/16 inch flange, and a 3/8 inch by .7 inch web. Note that the program asked the user if the center web was to take bending. Normal balsa shear webs with their grain vertical shouldn't be counted on for bending strength so the user answered "n" for no. Since there is only one material undergoing bending the program did not prompt the user for any Es information.

After the geometry and Es information is entered, the program will ask if you want to perform an analysis or a design. If you choose to do an analysis, the program will ask for the maximum allowable stresses, and it will output the maximum load that the section take tolerate. If you choose to do a design, the program will prompt the user for the design moment and shear, and it will output the actual stresses. In Example 1 for the CBA program I chose the design option, and entered the 102 inch * pound moment and 5 pound shear obtained from Example 3 for the WSM program. The program computed the bending stress on the section to be 1945 Psi, and the shear stress to be 19 Psi. Since the bending stress at the proportional limit (beginning of failure) for Sitka Spruce from the Wood Handbook is 4780 Psi, and the allowable shear is 1150 Psi the design is conservative. Since the G factor from Example 3 for the WSM program is 3.5, this spar design can probably take $(3.5 \times 4780/1945)$, or 8.6 Gs. This is equivalent to supporting 24 lbs statically on the wing, which seems reasonable.

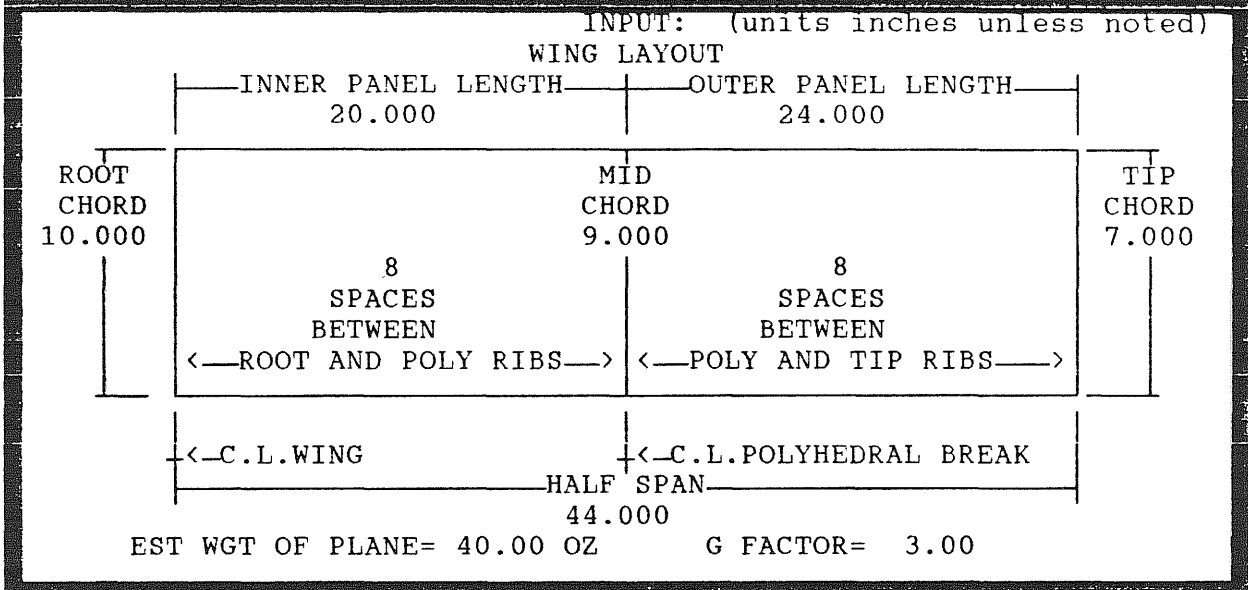
Example 2 for the CBA program illustrates a more complex design. Suppose that the same height restriction as the previous example are used, but maximum strength must be realized from this design. The designer has decided that the main flanges are to be 1/4 inch by 1/2 inch in cross section. To keep the same depth the distance between flanges is now entered as .56 inch. The auxiliary flanges are added by indicating their dimensions as .007 inch by 1/2 inch. Since the new wing will be made of foam core, the auxiliary webs can be continuous and can therefore take some bending stress. They are dimensioned as being 1/8 inch thick. Since the auxiliary flanges were specified, the program prompts the designer for the Es of both the auxiliary and main flanges. The Es of the main flanges is that of spruce, 1570 Ksi. The auxiliary flanges are assumed to be made of carbon fiber and to be 5 times stiffer than spruce, so the Es is entered as 7850 Ksi. The program asks the designer if the outer webs can withstand any bending action. The designer entered a "y" for yes and the program then prompted him for the Es of the outer webs. They are assumed to be plywood with a stiffness 1/2th that of spruce, or 785 Ksi. Similar questions are asked by the program concerning the shear in the center and outer webs. Since I don't have any information on the shear moduli of materials I guessed at the shear stiffnesses of the materials. For the outer plywood webs I assumed the shear modulus to be 785 Ksi, and the balsa center web to have a value of 1/10th that of the plywood webs, or 78.5 Ksi. It is important to realize that only the ratios of the Es or the shear moduli are important, not the actual values.

When the program prompted for the type of calculation, an analysis was chosen. The program then asked for the allowable stresses of each component, and 11,000 Psi was chosen for carbon fiber, and 4780 Psi was chosen for spruce and plywood. The results give the maximum loads that the spar can withstand as 265 inch * pounds of moment, and 97 pounds of vertical shear. The output also shows that the carbon fiber auxiliary flanges reached critical stress first since the maximum stresses are equal to the allowable stress of 11000 Psi. The main flange stresses, however, are not close to their allowable stress so the design is not well balanced, assuming the strength values that were input are valid. Using the ratio of the moments between these 2 examples shows that the composite section can take 2.6 times more load than was originally specified for Example 1.

Summary

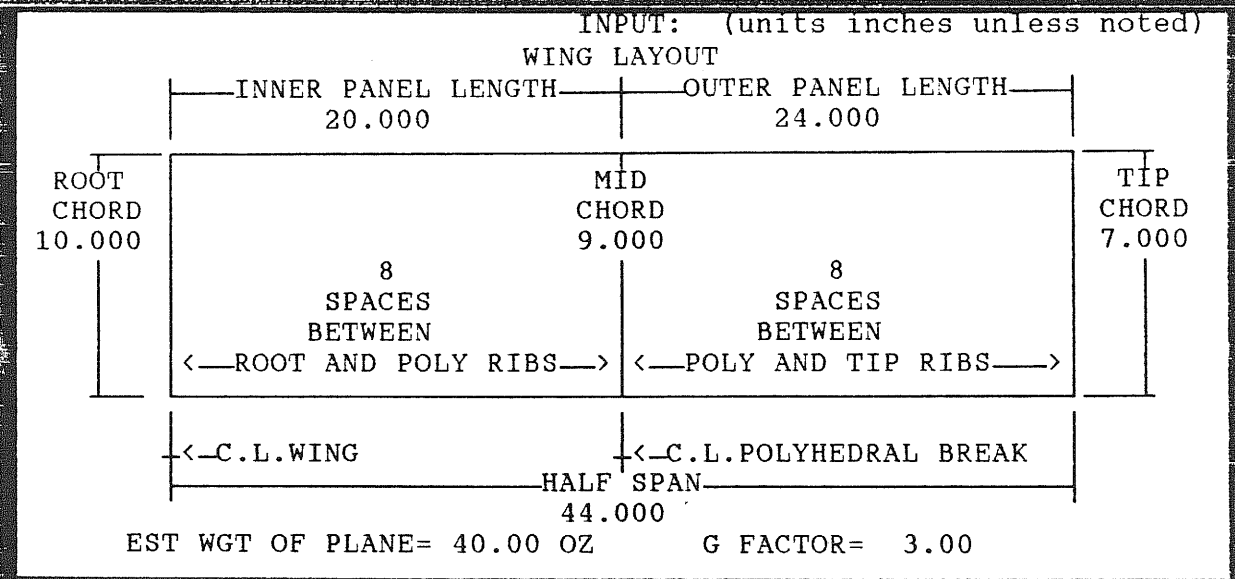
The above programs are tools that can be useful to the modeler. The WSM program can help the modeler determine the spar loads associated with a wing planform. The CBA program can help the modeler size complex spar configurations, involving materials of varying stiffness.

WING SHEAR-MOMENT PROGRAM by: S. R. Pituch
 TITLE: EXAMPLE 1



RESULTS: Loads with G factor included			
	STATION	SHEAR LBS	MOMENT IN*LBS
AT TIP RIB	0	0.0	0.0
	1	0.210	0.313
	2	0.427	1.266
	3	0.652	2.882
	4	0.884	5.183
	5	1.123	8.191
	6	1.369	11.927
AT POLYHEDRAL RIB	7	1.623	16.415
	8	1.885	21.675
	9	2.107	26.665
	10	2.333	32.214
	11	2.561	38.331
	12	2.793	45.023
	13	3.028	52.298
AT ROOT RIB	14	3.265	60.163
	15	3.506	68.627
	16	3.750	77.696
INNER PANEL AREAS TOTAL =		380.0 SQIN	
OUTER PANEL AREAS TOTAL =		384.0 SQIN	
TOTAL WING AREA TOTAL =		764.0 SQIN	
WING LOADING (W/O G FACT)=		7.54 OZ/SQFT	
DIHEDRAL= 5.00 DEG POLYHEDRAL=10.00 DEG			
ROLLING DIHEDRAL MOMENT FACTOR =		138.9	

WING SHEAR-MOMENT PROGRAM by: S. R. Pituch
 TITLE: EXAMPLE 2



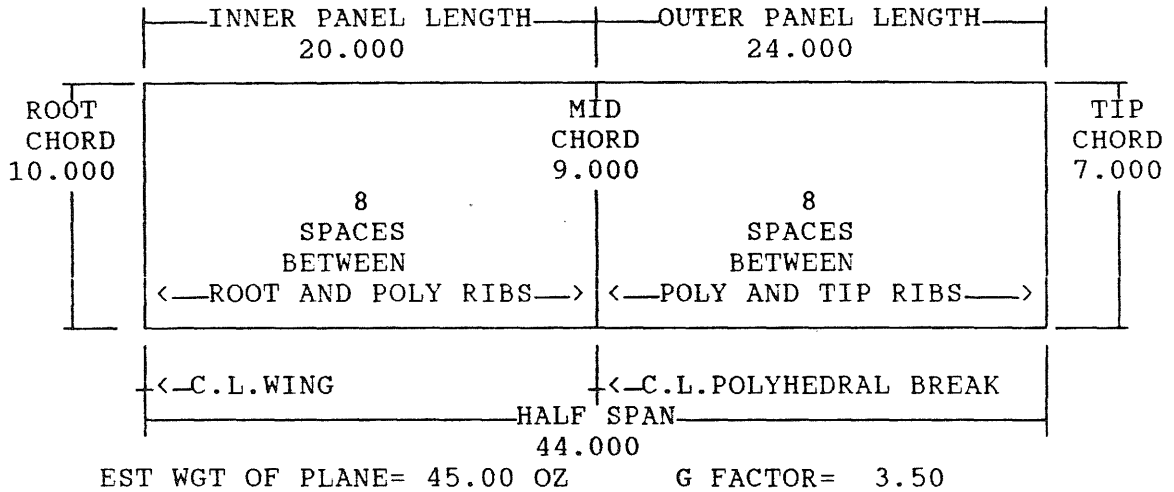
RESULTS: Loads with G factor included

	STATION	SHEAR LBS	MOMENT IN*LBS
AT TIP RIB	0	0.0	0.0
	1	0.210	0.313
	2	0.427	1.266
	3	0.652	2.882
	4	0.884	5.183
	5	1.123	8.191
	6	1.369	11.927
	7	1.623	16.415
AT POLYHEDRAL RIB	8	1.885	21.675
	9	2.107	26.665
	10	2.333	32.214
	11	2.561	38.331
	12	2.793	45.023
	13	3.028	52.298
	14	3.265	60.163
	15	3.506	68.627
AT ROOT RIB	16	3.750	77.696
INNER PANEL AREAS TOTAL =		380.0 SQIN	
OUTER PANEL AREAS TOTAL =		384.0 SQIN	
TOTAL WING AREA TOTAL =		764.0 SQIN	
WING LOADING (W/O G FACT) =		7.54 OZ/SQFT	
DIHEDRAL = 0.00 DEG		POLYHEDRAL = 15.00 DEG	
ROLLING DIHEDRAL MOMENT FACTOR =		147.9	

WING SHEAR-MOMENT PROGRAM by: S. R. Pituch
 TITLE: EXAMPLE 3

INPUT: (units inches unless noted)

WING LAYOUT



RESULTS: Loads with G factor included

	STATION	SHEAR LBS	MOMENT IN*LBS
AT TIP RIB	0	0.0	0.0
	1	0.275	0.411
	2	0.560	1.662
	3	0.855	3.783
	4	1.160	6.803
	5	1.474	10.750
	6	1.797	15.655
	7	2.131	21.544
AT POLYHEDRAL RIB	8	2.474	28.449
	9	2.766	34.998
	10	3.062	42.281
	11	3.362	50.309
	12	3.666	59.093
	13	3.974	68.641
	14	4.286	78.964
	15	4.602	90.073
AT ROOT RIB	16	4.922	101.976
INNER PANEL AREAS TOTAL =		380.0 SQIN	
OUTER PANEL AREAS TOTAL =		384.0 SQIN	
TOTAL WING AREA TOTAL =		764.0 SQIN	
WING LOADING (W/O G FACT)=		8.48 OZ/SQFT	
DIHEDRAL= 0.00 DEG		POLYHEDRAL=15.00 DEG	
ROLLING DIHEDRAL MOMENT FACTOR =		147.9	

```

1170 LPRINT [";SPC(13);"WING SHEAR-MOMENT PROGRAM by: S. R. Pituch";SPC(11);"["
1180 LPRINT[" TITLE: ";TITLES;" ["
1190 LPRINT [";STRINGS(67,220);"["
1200 LPRINT [";SPC(31);"INPUT: (units inches unless noted) ["
1210 LPRINT [";SPC(28);"WING LAYOUT";SPC(28);"["
1220 LPRINT [";SPC(8);"CDDINNER PANEL LENGTHHDDDDOUTER PANEL LENGTHHDD4";SPC(8);"["
1230 A=0
1240 LPRINT [";SPC(8);"3";SPC(8);:IF A1=0! THEN LPRINT SPC(6); ELSE LPRINT USING "##.###";A1;
1250 LPRINT SPC(10);"3";SPC(8);:IF A2=0! THEN LPRINT SPC(6); ELSE LPRINT USING "##.###";A2;
1260 LPRINT SPC(10);"3";SPC(8);"["
1270 LPRINT [";SPC(4);"BDDZ";STRING$(24,196);"B";STRING$(24,196);"?DDDB ["
1280 LPRINT [" ROOT 3";SPC(23);"MID";SPC(23);"3 TIP ["
1290 LPRINT [" CHORD 3";SPC(22);"CHORD";SPC(22);"3 CHORD ["
1300 LPRINT [" ";:IF A3=0! THEN LPRINT " 3 ";ELSE LPRINT USING "##.###";A3;
1310 LPRINT " 3";SPC(21);:IF A4=0! THEN LPRINT " 3 ";ELSE LPRINT USING "##.###";A4;
1320 LPRINT SPC(22);"3";:IF A5=0! THEN LPRINT " 3";ELSE LPRINT USING "##.###";A5;
1330 LPRINT " ["
1340 LPRINT [" 3 3";SPC(10);:IF A6=0 THEN LPRINT " ";ELSE LPRINT USING "##";A6%;
1350 LPRINT SPC(12);"3";SPC(10);:IF A7=0 THEN LPRINT " ";ELSE LPRINT USING "##";A7%;
1360 LPRINT SPC(12);"3 3 ["
1370 LPRINT [" 3 3";SPC(8);"SPACES";SPC(10);"3";SPC(8);"SPACES";SPC(10);
1380 LPRINT "3 3 ["
1390 LPRINT [" 3 3";SPC(7);"BETWEEN";SPC(10);"3";SPC(7);"BETWEEN";SPC(10);
1400 LPRINT "3 3 ["
1410 LPRINT [" 3 3<DDROOT AND POLY RIBSDD>3<DDPOLY AND TIP RIBSDDD>3 3 ["
1420 LPRINT [" ADD @";STRING$(24,196);"A";STRING$(24,196);"YDDDA ["
1430 LPRINT [";SPC(8);"3";SPC(24);"3";SPC(24);"3";SPC(8);"["
1440 LPRINT [";SPC(8);"E<DC.L.WING";SPC(14);"E<DC.L.POLYHEDRAL BREAK 3";SPC(8);"["
1450 LPRINT [";SPC(8);"C";STRING$(20,196);"HALF SPAN";STRING$(20,196);"4";SPC(8);"["
1460 LPRINT [";SPC(30);:IF A8=0! THEN LPRINT SPC(6);ELSE LPRINT USING "##.###";A8;
1470 LPRINT SPC(31);"["
1480 LPRINT [" EST WGT OF PLANE= ";:IF A9=0! THEN LPRINT " ";ELSE LPRINT USING "##.###";A9;
1490 LPRINT " OZ G FACTOR= ";:IF A10=0! THEN LPRINT " ";ELSE LPRINT USING "##.###";A10;
1500 LPRINT SPC(14);"["
1510 LPRINT [";STRINGS(67,220);"["
1520 LPRINT "Z";STRING$(42,196);"?
1530 LPRINT "3 RESULTS: Loads with G factor included 3"
1540 LPRINT "C";STRING$(17,196);"B";STRING$(7,196);"B";STRING$(7,196);"B";STRING$(8,196);"4"
1550 LPRINT "3";SPC(17);"3STATION3 SHEAR 3 MOMENT 3"
1560 LPRINT "3";SPC(17);"3 3 LBS 3 IN*LBS 3"
1570 LPRINT "C";STRING$(17,196);"E";STRING$(7,196);"E";STRING$(7,196);"E";STRING$(8,196);"4"
1580 I4%=0
1590 LPRINT "3 AT TIP RIB3 0 3 0.0 3 0.0 3"
1600 FOR I4%=1 TO I3%
1610 IF I4%=OUTSP% THEN 1640
1620 IF I4%=I3% THEN 1650
1630 LPRINT "3";SPC(17);"3 ";:LPRINT USING "##";I4%;:LPRINT " 3 ";:LPRINT USING "##.###";
SHEAR(I4%)/16!;:LPRINT "3";:LPRINT USING "###.###";MOM(I4%)/16!;:LPRINT "3":GOTO 1660
1640 LPRINT "3AT POLYHEDRAL RIB3 ";:LPRINT USING "##";I4%;:LPRINT " 3 ";:LPRINT USING "##.###";
SHEAR(I4%)/16!;:LPRINT "3";:LPRINT USING "###.###";MOM(I4%)/16!;:LPRINT "3":GOTO 1660
1650 LPRINT "3 AT ROOT RIB3 ";:LPRINT USING "##";I4%;:LPRINT " 3 ";:LPRINT USING "##.###";
SHEAR(I4%)/16!;:LPRINT "3";:LPRINT USING "###.###";MOM(I4%)/16!;:LPRINT "3":GOTO 1660
1660 NEXT I4%
1670 LPRINT "C";STRING$(17,196);"A";STRING$(7,196);"A";STRING$(7,196);"A";STRING$(8,196);"4"
1680 LPRINT "3 INNER PANEL AREAS TOTAL = ";:LPRINT USING "###.#";W1;:LPRINT " SQIN3"
1690 LPRINT "C";STRING$(42,196);"4"
1700 LPRINT "3 OUTER PANEL AREAS TOTAL = ";:LPRINT USING "###.#";W2;:LPRINT " SQIN3"
1710 LPRINT "C";STRING$(42,196);"4"

```

```

1720 LPRINT "3 TOTAL WING AREA TOTAL = ";LPRINT USING "####.#";W3;LPRINT " SQIN3"
1730 LPRINT "C";STRING$(42,196);"4"
1740 LPRINT "3WING LOADING (W/O G FACT)= ";LPRINT USING "##.##";W4;LPRINT " OZ/SQFT3"
1750 LPRINT "C";STRING$(42,196);"4"
1760 LPRINT "3 DIHEDRAL=";LPRINT USING "##.##";(BR*180!/3.14159);LPRINT " DEG"; TAB(23);
      "POLYHEDRAL=";LPRINT USING "##.##";(BM*180!/3.14159);LPRINT " DEG";TAB(44);"3"
1770 LPRINT "C";STRING$(42,196);"4"
1780 LPRINT "3ROLLING DIHEDRAL MOMENT FACTOR = ";LPRINT USING "####.#";MOMTOT;LPRINT " 3"
1790 LPRINT "@";STRING$(42,196);"Y"
1800 CLS
1810 PRINT "^";STRING$(57,223);"]"
1820 PRINT "^ If you want to end program, then type an E;";PRINT TAB(59);"]"
1830 PRINT "^ If you want to recycle the entire program,;";PRINT TAB(59);"]"
1840 PRINT "^ then type an R;";PRINT TAB(59);"]"
1850 PRINT "^ If you want to reuse geometry but reenter new;";PRINT TAB(59);"]"
1860 PRINT "^ weight and G factor, then type a G;";PRINT TAB(59);"]"
1870 PRINT "^ If you want to reuse geometry but reenter new;";PRINT TAB(59);"]"
1880 PRINT "^ hedral angles, then type an A.;";PRINT TAB(59);"]"
1890 PRINT "^";STRING$(57,220);"]"
1900 A$=INKEY$:IF A$="" THEN GOTO 1900
1910 IF A$="E" OR A$="e" THEN END
1920 IF A$="G" OR A$="g" THEN CLS:GOTO 80
1930 IF A$="A" OR A$="a" THEN CLS:GOTO 80
1940 IF A$="R" OR A$="r" THEN CLS:GOTO 70
1950 GOTO 1800

```


COMPOSITE BEAM ANALYSIS PROGRAM :by S.Pituch

INPUT

(default units are:inch,pounds,inch*pounds,psi)

EXAMPLE 1

Width of MAIN flange,WF1,equals 0.375 inches

Thick of top MAIN flange,TF1,equals 0.188inches

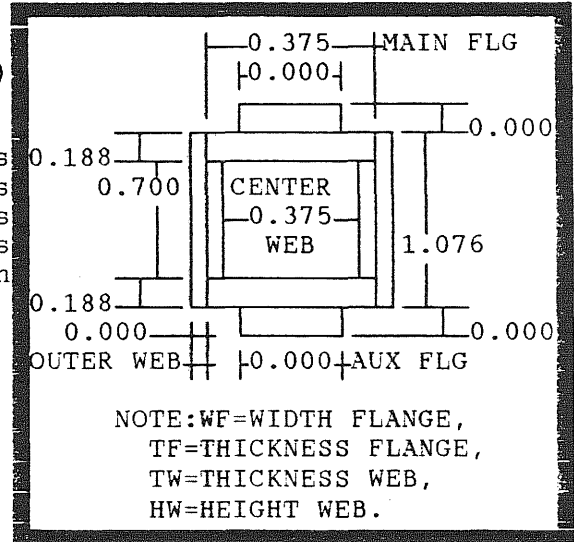
Thick of bot MAIN flange,TF2 equals 0.188inches

Distance between MAIN flanges,HW1 =0.700 inches

Thickness of CENTER web,TW1,equals 0.375 inches

The OUTER webs are not used in this calculation
Top AUX flange is not used in this calculation

Bot AUX flange is not used in this calculation



NOTE:WF=WIDTH FLANGE,
TF=THICKNESS FLANGE,
TW=THICKNESS WEB,
HW=HEIGHT WEB.

Center web does not take any bending.

RESULTS

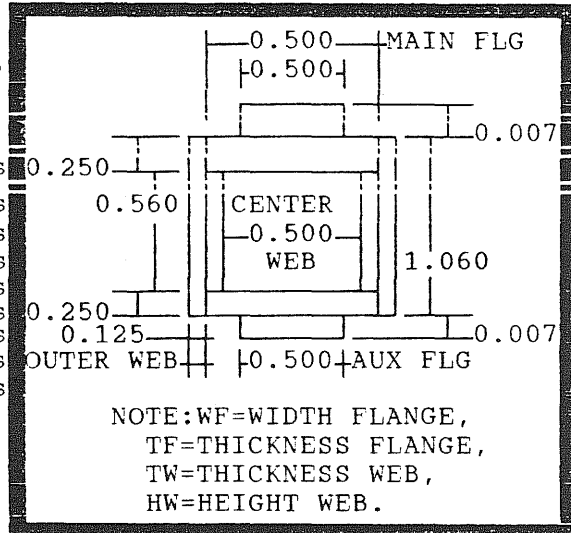
Max bend stress top main flange: -1945.17 PSI
 Max bend stress bot main flange: 1945.17 PSI
 Max shear stress center web : 19.05 PSI
 Applied moment equals 102.000 inch*pounds
 Applied shear equals 5.000 pounds
 The moment of inertia of the entire
 section with respect to the stiffness
 of the main flanges equals: 0.02821(inch**4)

COMPOSITE BEAM ANALYSIS PROGRAM :by S.Pituch
 INPUT

(default units are:inch,pounds,inch*pounds,psi)

EXAMPLE 2

Width of MAIN flange,WF1,equals 0.500 inches
 Thick of top MAIN flange,TF1,equals 0.250inches
 Thick of bot MAIN flange,TF2 equals 0.250inches
 Disthance between MAIN flanges,HW1 =0.560 inches
 Thickness of CENTER web,TW1,equals 0.500 inches
 Thickness of OUTER webs,TW2,equals 0.125 inches
 Thick of top AUX flange,TF3,equals 0.007 inches
 Width of top AUX flange,TF3,equals 0.500 inches
 Thick of bot AUX flange,TF4,equals 0.007 inches
 Width of bot AUX flange,WF4,equals 0.500 inches
 Mod of elas of MAIN flgs = 1570.000 KSI
 Mod of elas of AUX flgs = 7850.000 KSI
 Mod of elas of OUTER webs = 785.000 KSI
 Center web does not take any bending.
 Shear mod of OUTER webs equals 785.000 KSI
 Shear mod of CENTER web equals 78.500 KSI



RESULTS

Max bend stress top main flange: -2171.32 PSI
 Max bend stress bot main flange: 2171.32 PSI
 Design bend stress main flanges: 4780.00 PSI
 Max bend stress top aux flange: -11000.00 PSI
 Max bend stress bot aux flange: 11000.00 PSI
 Design bend stress aux flanges: 11000.00 PSI
 Max bend stress top outer webs: -1085.66 PSI
 Max bend stress bot outer webs: 1085.66 PSI
 Design bend stress outer webs: 4780.00 PSI
 Max shear stress center web : 115.00 PSI
 Design shear stress center web : 300.00 PSI
 Max shear stress outer webs: 1150.00 PSI
 Design shear stress outer webs: 1150.00 PSI
 The shear stress between top
 main and top aux flanges: 97.279 PSI
 The shear stress between bot
 main and bot aux flanges: 97.279 PSI
 For bending the bot aux flange governs
 For shear outer webs governs
 The max allowable moment equals 264.970 inch*pounds
 The max allowable shear equals 336.950 pounds
 The moment of inertia of the entire
 section with respect to the stiffness
 of the main flanges equals: 0.06468 (inch**4)

```

1 REM PROGRAM: CBA
2 REM PURPOSE: TO DETERMINE STRESSES IN COMPOSITE BEAMS
3 REM AUTHOR: S. PITUCH, DATE MAY 2, 1992
10 DEFSTR Z
20 KEY OFF
30 CLS
40 Z1=CHR$(179) 'LINE VERTICAL(3)
50 Z2=CHR$(180) 'TEE LEFT(4)
60 Z3=CHR$(191) 'CORNER NORTH EAST(?)
70 Z4=CHR$(192) 'CORNER SOUTH WEST(@)
80 Z5=CHR$(193) 'TEE UP(A)
90 Z6=CHR$(194) 'TEE DOWN(B)
100 Z7=CHR$(195) 'TEE RIGHT(C)
110 Z8=CHR$(196) 'LINE HORIZONTAL(D)
120 Z9=CHR$(197) 'CROSS(E)
130 Z0=CHR$(217) 'CORNER SOUTH EAST(Y)
140 ZA=CHR$(218) 'CORNER NORTH WEST(Z)
150 ZB=CHR$(219) 'BLOCK FULL([)
160 ZC=CHR$(223) 'BLOCK UPPER HALF(_)
170 ZD=CHR$(220) 'BLOCK LOWER HALF(\)
180 ZE=" COMPOSITE BEAM ANALYSIS PROGRAM :by S.Pituch  "
190 ZF=" "
200 ZZ2="          INPUT          "
210 ZZ3="          Introduction    "
220 REM WHEN Q NUMBER =0 NAME WILL DISPLAY ON SCHEMATIC AT RIGHT OF SCREEN;
230 REM WHEN Q NUMBER =1 VALUE OF DIMENSION WILL DISPLAY.
240 QWF1%=0:QWF3%=0:QWF4%=0:QTF10%=0:QTF2%=0:QTF3%=0:QTF4%=0:QTW1%=0:QTW2%=0:QHW1%=0:QHW2%=0
250 REM T NUMBERS ARE FOR SWITCHING INFO ON LEFT OF SCREEN LINES 1 THROUGH 18;
260 REM   IF T=0 BLANK LINE WILL DISPLAY.
270 ZG="(default units are:inch,pounds,inch*pounds,psi)"
280 ZG3="This program will calculate the bending and  "
290 ZH="(Enter zero if item is not to be in design)  "
300 ZD1="Enter a TITLE for this calculation,47 char max:"
310 ZH3="shear stresses of the components of the beam  "
320 ZI="Enter width of MAIN flange,WF1:  "
330 ZI2="Width of MAIN flange,WF1,equals ":ZI1=" inches  "
340 ZI3="shown at the right. Both main flanges must be  "
350 ZJ="Enter thickness of top MAIN flange,TF1:  "
360 ZJ2="Thick of top MAIN flange,TF1,equals ":ZJ1="inches"
370 ZJ3="specified: their width must be equal but they  "
380 ZK="Enter thickness of bot MAIN flange,TF2:  "
390 ZK2="Thick of bot MAIN flange,TF2 equals ":ZK1="inches"
400 ZK3="may have different thicknesses. The other  "
410 ZL="Enter distance between MAIN flgs,HW1:  "
420 ZL2="Distance between MAIN flanges,HW1 =" :ZL1=" inches"
430 ZL3="members are optional. The aux flanges can only  "
440 ZM="Enter thick. of CEN web,TW1,(0 for no CEN web):"
450 ZM2="Thickness of CENTER web,TW1,equals ":ZM1=" inches"
460 ZM3="take bending, while the webs may take bending  "
470 ZM4="The CENTER web is not used in this calculation  "
480 ZN="Enter thick. of OUT webs,TW2,(0, no OUT webs): "
490 ZN2="Thickness of OUTER webs,TW2,equals ":ZN1=" inches"
500 ZN4="The OUTER webs are not used in this calculation"
510 ZN3="as well as shear. If the stiffness of the main  "
520 ZO="Enter thk top AUX flg,TF3,0 for no top AUX flg  "
530 ZO2="Thick of top AUX flange,TF3,equals ":ZO1=" inches"
540 ZO3="flanges, and the other bending members are not  "
550 ZO4="Top AUX flange is not used in this calculation  "

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```

560 ZP="Enter width of top AUX flange,WF3:      "
570 ZP2="Width of top AUX flange,TF3,equals  ":ZP1=" inches"
580 ZP3="equal, the bending loads are distributed using "
590 ZQ="Enter thk bot AUX flg,TF4,0 for no bot AUX flg "
600 ZQ2="Thick of bot AUX flange,TF4,equals  ":ZQ1=" inches"
610 ZQ3="an equivalent transformed area method utilizing"
620 ZQ4="Bot AUX flange is not used in this calculation "
630 ZR="Enter width of bot AUX flange,WF4:      "
640 ZR2="Width of bot AUX flange,WF4,equals  ":ZR1=" inches"
650 ZR3="the ratio of the moduli of elasticity. Thus it"
660 ZS="Enter mod of elas of MAIN flanges,(KSI):  "
670 ZS2="Mod of elas of MAIN flgs =   ":ZS1=" KSI   "
680 ZS3="can simulate carbon fiber reinforcing strips  "
690 ZT="Enter mod of elas of AUX flanges,(KSI):  "
700 ZT2="Mod of elas of AUX flgs =   ":ZT1=" KSI   "
710 ZT3="over spruce spars, etc. If the shear stiffness "
720 ZU="Are OUTER webs to also take bending?(Y or N): "
730 ZA1="Is CENTER web to also take bending?(Y or N): "
740 ZU2="Outer webs do not take any bending.      "
750 ZA2="Center web does not take any bending.    "
760 ZU3="of the center and outer webs are not equal "
770 ZV="Enter mod of elas of OUTER webs,(KSI):  "
780 ZA3="Enter mod of elas of CENTER web,(KSI):  "
790 ZV2="Mod of elas of OUTER webs =   ":ZV1=" KSI   "
800 ZA4="Mod of elas of CENTER web =   ":ZA5=" KSI   "
810 ZV3="the shear loads are distributed in a similar "
820 ZW="Enter shear modulus of CENTER web,(KSI): "
830 ZW2="Shear mod of CENTER web equals ":ZW1=" KSI   "
840 ZW3="manner. A summary page is displayed at the end "
850 ZX="Enter shear modulus of OUTER webs,(KSI): "
860 ZX2="Shear mod of OUTER webs equals ":ZX1=" KSI   "
870 ZC1="Enter moment load on the section,(inch*pounds):"
880 ZB1="Enter the shear load on the section,(pounds): "
890 ZC2="Moment load on the section = ":ZC3=" inch*pounds "
900 ZB2="Shear load on the section equals  ":ZB3=" pounds "
910 ZX3="of the computation and can be printed out for documentation. The program can be completely
      recycled, or the geometry saved and just the loads changed for the next run. This feature
      makes it relatively easy to home in on the maximum"
920 ZY3="capacity of a section using trial and error."
930 REM PRINT OUT INTRODUCTION
940 T1%=1:T2%=1:T3%=1:T4%=1:T5%=1:T6%=1:T7%=1:T8%=1:T9%=1:T10%=1:T11%=1:T12%=1:T13%=1:T14%=1:T15%=1:
      T16%=1:T17%=1:T18%=1:T19%=1:T20%=1
950 CLS
960 GOSUB 2130
970 LOCATE 25,1 :PRINT "                PRESS ANY KEY TO START                ";
980 A$=INKEY$:IF A$="" THEN 980
990 T1%=2:T2%=2:T3%=2:T4%=2:T5%=0:T6%=0:T7%=0:T8%=0:T9%=0:T10%=0:T11%=0:T12%=0:T13%=0:T14%=0:T15%=0:
      T16%=0:T17%=0:T18%=0:T19%=0
1000 CLS
1010 GOSUB 2130
1020 INPUT WF1!
1030 T4%=3:QWF1=1:T5%=2
1040 CLS
1050 GOSUB 2130
1060 INPUT TF1!
1070 T5%=3:QTF1=1:T6%=2
1080 CLS
1090 GOSUB 2130

```

```

1100 INPUT TF2!
1110 T6%=3:QTF2=1:T7%=2
1120 CLS
1130 GOSUB 2130
1140 INPUT HW1!
1150 HW2!=TF1!+TF2!+HW1!:QHW2=1
1160 T7%=3:QHW1=1:T8%=2
1170 CLS
1180 GOSUB 2130
1190 INPUT TW1!
1200 IF TW1!=0! THEN T8%=4 ELSE T8%=3
1210 QTW1=1:T9%=2
1220 CLS
1230 GOSUB 2130
1240 INPUT TW2!
1250 IF TW2!=0 THEN T9%=4 ELSE T9%=3
1260 QTW2=1:T10%=2
1270 CLS
1280 GOSUB 2130
1290 INPUT TF3!
1300 IF TF3!=0! THEN T10%=4:T12%=2:WF3%=0!:QWF3=1:QTF3=1:GOTO 1360 ELSE T10%=3
1310 QTF3=1:T11%=2
1320 CLS
1330 GOSUB 2130
1340 INPUT WF3!
1350 T11%=3:QWF3=1:T12%=2
1360 CLS
1370 GOSUB 2130
1380 INPUT TF4!
1390 IF TF4!=0! THEN T12%=4:T15%=2:WF4!=0!:QWF4=1:QTF4=1:GOTO 1450 ELSE T12%=3
1400 QTF4=1:T13%=2
1410 CLS
1420 GOSUB 2130
1430 INPUT WF4!
1440 T13%=3:QWF4=1:T15%=2
1450 IF TF3!=0! AND TF4!=0 THEN T15%=0:EAF!=0!:GOTO 1500
1460 CLS
1470 GOSUB 2130
1480 INPUT EAF!
1490 IF EAF!(<>)0! THEN T15%=3
1500 IF TW2! = 0! THEN EOW!=0!:T16%=0:T17%=2:GOTO 1610
1510 T16%=2
1520 CLS
1530 GOSUB 2130
1540 INPUT QUES$
1550 IF QUES$ = "N" OR QUES$ = "n" THEN EOW!=0!:T16%=4:GOTO 1610 ELSE T16%=5
1560 CLS
1570 GOSUB 2130
1580 INPUT EOW!
1590 T16%=3
1600 IF EOW!=0! THEN GOTO 1560
1610 IF TW1! = 0! THEN ECW!=0!:T17%=0:GOTO 1720
1620 T17%=2
1630 CLS
1640 GOSUB 2130
1650 INPUT QUES$
1660 IF QUES$ = "N" OR QUES$ = "n" THEN ECW!=0!:T17%=4:GOTO 1720 ELSE T17%=5
1670 CLS

```



```

2810 IF T9%=3 THEN PRINT USING "#.###";TW2!;
2820 IF T9%=3 THEN PRINT ZN1;
2830 PRINT ZB;"      ";Z8;Z6;Z5;Z8;Z1;Z7;Z5;Z8;Z8;Z8;Z8;Z8;Z8;Z8;Z5;Z2;Z1;" ";Z1;"      ";ZB;
2840 IF T10%=0 THEN PRINT ZF;
2850 IF T10%=1 THEN PRINT Z03;
2860 IF T10%=2 THEN PRINT Z0;
2870 IF T10%=3 THEN PRINT Z02;
2880 IF T10%=3 THEN PRINT USING "#.###";TF3;
2890 IF T10%=3 THEN PRINT Z01;
2900 IF T10%=4 THEN PRINT Z04;
2910 PRINT ZB;:IF QTF2=0 THEN PRINT "  TF2";ELSE PRINT USING "#.###";TF2!;
2920 PRINT Z8;Z5;Z8;Z8;Z4;Z5;Z8;Z6;Z8;Z8;Z8;Z8;Z6;Z8;Z5;Z0;Z8;Z5;Z6;Z8;"      ";ZB;
2930 IF T11%=0 THEN PRINT ZF;
2940 IF T11%=1 THEN PRINT ZP3;
2950 IF T11%=2 THEN PRINT ZP;
2960 IF T11%=3 THEN PRINT ZP2;
2970 IF T11%=3 THEN PRINT USING "#.###";WP3!;
2980 IF T11%=3 THEN PRINT ZP1;
2990 PRINT ZB;" ";:IF QTW2=0 THEN PRINT "  TW2";ELSE PRINT USING "#.###";TW2!;
3000 PRINT Z8;Z8;Z9;Z9;" ";Z4;Z8;Z8;Z8;Z8;Z8;Z0;Z8;Z8;Z8;Z8;Z5;Z8;:
      IF QTF4=0 THEN PRINT "TF4 ";ELSE PRINT USING "#.###";TF4!;
3010 PRINT ZB;
3020 IF T12%=0 THEN PRINT ZF;
3030 IF T12%=1 THEN PRINT ZQ3;
3040 IF T12%=2 THEN PRINT ZQ;
3050 IF T12%=3 THEN PRINT ZQ2;
3060 IF T12%=3 THEN PRINT USING "#.###";TF4!;
3070 IF T12%=3 THEN PRINT ZQ1;
3080 IF T12%=4 THEN PRINT ZQ4;
3090 PRINT ZB;"OUTER WEB";Z9;Z9;" ";Z7;:IF QWF4=0 THEN PRINT "DWF4D";ELSE PRINT USING "#.###";WF4!;
3100 PRINT Z9;"AUX FLG      ";ZB;
3110 IF T13%=0 THEN PRINT ZF;
3120 IF T13%=1 THEN PRINT ZR3;
3130 IF T13%=2 THEN PRINT ZR;
3140 IF T13%=3 THEN PRINT ZR2;
3150 IF T13%=3 THEN PRINT USING "#.###";WF4!;
3160 IF T13%=3 THEN PRINT ZR1;
3170 PRINT ZB;"      ";ZB;
3180 IF T15%=0 THEN PRINT ZF;
3190 IF T15%=1 THEN PRINT ZS3;
3200 IF T15%=2 THEN PRINT ZT;
3210 IF T15%=3 THEN PRINT ZT2;
3220 IF T15%=3 THEN PRINT USING "#####.###";BAF!;
3230 IF T15%=3 THEN PRINT ZT1;
3240 PRINT ZB;"      NOTE:WF=WIDTH FLANGE,      ";ZB;
3250 IF T16%=0 THEN PRINT ZF;
3260 IF T16%=1 THEN PRINT ZT3;
3270 IF T16%=2 THEN PRINT ZU;
3280 IF T16%=3 THEN PRINT ZV2;
3290 IF T16%=3 THEN PRINT USING "#####.###";BOW!;
3300 IF T16%=3 THEN PRINT ZV1;
3310 IF T16%=4 THEN PRINT ZU2;
3320 IF T16%=5 THEN PRINT ZV;
3330 PRINT ZB;"      TF=THICKNESS FLANGE,      ";ZB;
3340 IF T17%=0 THEN PRINT ZF;
3350 IF T17%=1 THEN PRINT ZU3;
3360 IF T17%=2 THEN PRINT ZA1;
3370 IF T17%=3 THEN PRINT ZA4;

```



```

3920 PRINT "Enter the design shear stress for the outer webs, (psi):"
3930 INPUT ALOTWBSH!
3940 MOM!=1!:SHR!=1!
3950 REM goto calc routine
3960 GOSUB 4420
3970 REM find the largest ratio of actual bending stress to allowable bending stress.
3980 RATIO1!=ABS(BDSTR1!/ALMNFLBD!)
3990 RATIO2!=ABS(BDSTR2!/ALMNFLBD!)
4000 IF RATIO1! >= RATIO2! THEN MAXRAT1!=RATIO1!:MAX1$=" top main flange " ELSE
    MAXRAT1!=RATIO2!:MAX1$=" bot main flange "
4010 IF TF3!=0! GOTO 4040
4020 RATIO1!=ABS(BDSTR3!/ALAXFLBD!)
4030 IF RATIO1! >= MAXRAT1! THEN MAXRAT1!=RATIO1!:MAX1$=" top aux flange "
4040 IF TF4!=0! GOTO 4070
4050 RATIO1!=ABS(BDSTR4!/ALAXFLBD!)
4060 IF RATIO1! >= MAXRAT1! THEN MAXRAT1!=RATIO1!:MAX1$=" bot aux flange "
4070 IF TW1!=0! OR ECW!=0! GOTO 4120
4080 RATIO1!=ABS(BDSTR5!/ALCNWBBD!)
4090 IF RATIO1! >= MAXRAT1! THEN MAXRAT1!=RATIO1!:MAX1$=" top center web "
4100 RATIO1!=ABS(BDSTR6!/ALCNWBBD!)
4110 IF RATIO1! >= MAXRAT1! THEN MAXRAT1!=RATIO1!:MAX1$=" bot center web "
4120 IF TW2!=0! OR EOW!=0! GOTO 4170
4130 RATIO1!=ABS(BDSTR7!/ALOTWBBD!)
4140 IF RATIO1! >= MAXRAT1! THEN MAXRAT1!=RATIO1!:MAX1$=" top outer webs "
4150 RATIO1!=ABS(BDSTR8!/ALOTWBBD!)
4160 IF RATIO1! >= MAXRAT1! THEN MAXRAT1!=RATIO1!:MAX1$=" bot outer webs "
4170 RATIO1!=ABS(CSHRSTR!/ALCNWBSH!)
4180 RATIO2!=ABS(OSHRSTR!/ALOTWBSH!)
4190 IF RATIO1! >= RATIO2! THEN MAXRAT2!=RATIO1!:MAX2$=" center web " ELSE
    MAXRAT2!=RATIO2!:MAX2$=" outer webs "
4200 IF MAXRAT2!=0! THEN MAX2$ = " no shear webs ":GOTO 4220
4210 REM the reciprocal of the ratios is the new allowable bending and shear loads.
4215 SHR!=1!/MAXRAT2!
4220 MOM!=1!/MAXRAT1!
4230 GOTO 4290 'go to calc routine
4240 REM if here then design mode
4250 PRINT ZC1
4260 INPUT MOM!
4270 PRINT ZB1
4280 INPUT SHR!
4290 RETURN
4300 REM end of moment shear choice routine
4310 REM
4320 REM
4330 REM THIS SUBROUTINE MAKES THE TITLE EXACTLY 47 CHARS.
4340 COUNT%=LEN(TITLE$)
4350 IF COUNT%>47 THEN TEMPS=LEFT$(TITLE$,47):TITLE$=TEMPS:RETURN
4360 IF COUNT%<47 THEN TITLE$=TITLE$+SPACES(47-COUNT%)
4370 RETURN
4380 REM
4390 REM
4400 REM THIS SUBROUTINE DOES THE CALCULATION.
4410 REM FIND CENTROID IN REF TO TOP OF TOP MAIN FLG. TRANSFORM AREAS FOR
    BENDING USING E RATIOS. MAIN FLG AREA IS CONSTANT.
4420 IF EMP!=0! THEN EMP!=1!
4430 EBAP!=EAF!:ETAF!=EAF!
4440 AREA1!=TF1!*WF1!:AREA2!=TF2!*WF1!:AREA4!=WF4!*TF4!*(EBAP!/EMP!):AREA3!=TF3!*WF3!*(ETAF!/EMP!):AREA5!=
    TW1!*HW1!*(ECW!/EMP!):AREA6!=2!*TW2!*HW2!*(EOW!/EMP!):AREA7!=AREA1!+AREA2!+AREA3!+AREA4!+AREA5!+AREA6!

```

```

4450 MOM1!=AREA1!*TF1!/2!
4460 MOM2!=AREA2!*(TF2!/2!+HW1!+TF1!)
4470 MOM4!=AREA4!*(HW2!+TF4!/2!)
4480 MOM3!=(1!)*AREA3!*TF3!/2!
4490 MOM5!=AREA5!*(HW1!/2!+TF1!)
4500 MOM6!=AREA6!*HW2!/2!
4510 MOM7!=MOM1!+MOM2!+MOM3!+MOM4!+MOM5!+MOM6!
4520 XBAR!=MOM7!/AREA7! 'XBAR IS DIST FROM TOP OF MAIN FLG TO CG OF TRANSFORMED
4530 'AREAS. FIND THE TOTAL MOMENT OF INERTIA OF THE TRANSFORMED SECTION.
4540 DIS1!=XBAR!-TF1!/2!
4550 DIS2!=HW2!-XBAR!-TF2!/2!
4560 DIS4!=HW2!-XBAR!+TF4!/2!
4570 DIS3!=XBAR!+TF3!/2!
4580 DIS5!=ABS(HW1!/2!+TF1!-XBAR!)
4590 DIS6!=ABS(HW2!/2!-XBAR!)
4600 REM MOMENTS OF INERTIA.
4610 MI1!=AREA1!*TF1!*TF1!/12!+AREA1!*DIS1!*DIS1!
4620 MI2!=AREA2!*TF2!*TF2!/12!+AREA2!*DIS2!*DIS2!
4630 MI3!=AREA3!*TF3!*TF3!/12!+AREA3!*DIS3!*DIS3!
4640 MI4!=AREA4!*TF4!*TF4!/12!+AREA4!*DIS4!*DIS4!
4650 MI5!=AREA5!*HW1!*HW1!/12!+AREA5!*DIS5!*DIS5!
4660 MI6!=AREA6!*HW2!*HW2!/12!+AREA6!*DIS6!*DIS6!
4670 MI7!=MI1!+MI2!+MI3!+MI4!+MI5!+MI6!
4680 FACTOR1!=MOM!/MI7!
4690 BDSTR1!=FACTOR1!*XBAR!*(-1!)
4700 BDSTR2!=FACTOR1!*(HW2!-XBAR!)
4710 BDSTR3!=FACTOR1!*(-1!)*(XBAR!+TF3!)*(ETAF!/EMF!)
4720 BDSTR4!=FACTOR1!*(HW2!+TF4!-XBAR!)*(EBAF!/EMF!)
4730 BDSTR5!=FACTOR1!*(-1!)*(XBAR!-TF1!)*(ECW!/EMF!)
4740 BDSTR6!=FACTOR1!*(HW2!-TF2!-XBAR!)*(BCW!/EMF!)
4750 BDSTR7!=FACTOR1!*(-1!)*(XBAR!*BOW!/EMF!)
4760 BDSTR8!=FACTOR1!*(HW2!-XBAR!)*(EOW!/EMF!)
4770 REM SHEAR DISTRIBUTION.
4780 IF TW1!(<0! AND TW2!(<0! THEN GOTO 4850
4790 IF TW1!=0! AND TW2!=0! THEN GOTO 4950
4800 IF TW1!=0! THEN GOTO 4830
4810 CAREA!=TW1!*HW1!:OAREA!=0!
4820 GOTO 4870
4830 OAREA!=2!*TW2!*HW2!:CAREA!=0!
4840 GOTO 4870
4850 CAREA!=TW1!*HW1!
4860 OAREA!=2!*TW2!*HW2!*SOW!/SCW!
4870 STOTAR!=CAREA!+OAREA!
4880 CENPERC!=CAREA!/STOTAR!
4890 OUTPERC!=1!-CENPERC!
4900 IF TW1!=0! THEN CSHRSTR!=0!:GOTO 4920
4910 CSHRSTR!=SHR!*CENPERC!/(TW1!*HW1!)
4920 IF TW2!=0! THEN OSHRSTR!=0!:GOTO 4951
4930 OSHRSTR!=SHR!*OUTPERC!/(2!*HW2!*TW2!)
4940 GOTO 4951
4950 CSHRSTR!=0!:OSHRSTR!=0!
4951 REM start shear flow between flgs calc
4952 IF WF3!=0! THEN GOTO 4955
4953 IF WF3!(<WF1! THEN MINWID!=WF3! ELSE MINWID!=WF1!
4954 IF AREA3!(>0! THEN SHRFL03!=(DIS3!*AREA3!)*SHR!/(MI7!*MINWID!)
4955 IF WF4!=0! THEN GOTO 4959
4956 IF WF4!(<WF1! THEN MINWID!=WF4! ELSE MINWID!=WF1!
4957 IF AREA4!(>0! THEN SHRFL04!=(DIS4!*AREA4!)*SHR!/(MI7!*MINWID!)

```



```

5510 IF T7%=3 THEN LPRINT ZL1;
5520 LPRINT ZB;"      "Z1;" ";Z1;Z1;Z7;Z8;;IF QTW1=0 THEN LPRINT "DTW1D";ELSE LPRINT USING "#.###";TW1!;
5530 LPRINT Z8;Z2;Z1;Z1;" ";Z1;"      ";ZB;
5540 IF T8%=0 THEN LPRINT ZF;
5550 IF T8%=1 THEN LPRINT ZM3;
5560 IF T8%=2 THEN LPRINT ZM;
5570 IF T8%=4 THEN LPRINT ZM4;
5580 IF T8%=3 THEN LPRINT ZM2;
5590 IF T8%=3 THEN LPRINT USING "#.###";TW1!;
5600 IF T8%=3 THEN LPRINT ZM1;
5610 LPRINT ZB;"      ";Z1;" ";Z1;Z1;Z1;" WEB ";Z1;Z1;Z1;;IF QHW2=0 THEN LPRINT "HW2 ";
      ELSE LPRINT USING "#.###";HW2!;
5620 LPRINT " ";ZB;
5630 IF T9%=0 THEN LPRINT ZF;
5640 IF T9%=1 THEN LPRINT ZN3;
5650 IF T9%=2 THEN LPRINT ZN;
5660 IF T9%=4 THEN LPRINT ZN4;
5670 IF T9%=3 THEN LPRINT ZN2;
5680 IF T9%=3 THEN LPRINT USING "#.###";TW2!;
5690 IF T9%=3 THEN LPRINT ZN1;
5700 LPRINT ZB;"      ";Z8;Z6;Z5;Z8;Z1;Z7;Z5;Z8;Z8;Z8;Z8;Z8;Z8;Z5;Z2;Z1;" ";Z1;"      ";ZB;
5710 IF T10%=0 THEN LPRINT ZF;
5720 IF T10%=1 THEN LPRINT Z03;
5730 IF T10%=2 THEN LPRINT Z0;
5740 IF T10%=3 THEN LPRINT Z02;
5750 IF T10%=3 THEN LPRINT USING "#.###";TF3;
5760 IF T10%=3 THEN LPRINT Z01;
5770 IF T10%=4 THEN LPRINT Z04;
5780 LPRINT ZB;;IF QTF2=0 THEN LPRINT " TF2";ELSE LPRINT USING "#.###";TF2!;
5790 LPRINT Z8;Z5;Z8;Z8;Z4;Z5;Z8;Z6;Z8;Z8;Z8;Z8;Z8;Z6;Z8;Z5;Z0;Z8;Z5;Z6;Z8;" ";ZB;
5800 IF T11%=0 THEN LPRINT ZF;
5810 IF T11%=1 THEN LPRINT ZP3;
5820 IF T11%=2 THEN LPRINT ZP;
5830 IF T11%=3 THEN LPRINT ZP2;
5840 IF T11%=3 THEN LPRINT USING "#.###";WF3!;
5850 IF T11%=3 THEN LPRINT ZP1;
5860 LPRINT ZB;" ";:IF QTW2=0 THEN LPRINT " TW2";ELSE LPRINT USING "#.###";TW2!;
5870 LPRINT Z8;Z8;Z9;Z9;" ";Z4;Z8;Z8;Z8;Z8;Z8;Z0;Z8;Z8;Z8;Z8;Z8;Z5;Z8;;IF QTF4=0 THEN LPRINT "TF4 ";
      ELSE LPRINT USING "#.###";TF4!;
5880 LPRINT ZB;
5890 IF T12%=0 THEN LPRINT ZF;
5900 IF T12%=1 THEN LPRINT ZQ3;
5910 IF T12%=2 THEN LPRINT ZQ;
5920 IF T12%=3 THEN LPRINT ZQ2;
5930 IF T12%=3 THEN LPRINT USING "#.###";TF4!;
5940 IF T12%=3 THEN LPRINT ZQ1;
5950 IF T12%=4 THEN LPRINT ZQ4;
5960 LPRINT ZB;"OUTER WEB";Z9;Z9;" ";Z7;;IF QWF4=0 THEN LPRINT "DWF4D";ELSE LPRINT USING "#.###";WF4!;
5970 LPRINT Z9;"AUX FLG ";ZB;
5980 IF T13%=0 THEN LPRINT ZF;
5990 IF T13%=1 THEN LPRINT ZR3;
6000 IF T13%=2 THEN LPRINT ZR;
6010 IF T13%=3 THEN LPRINT ZR2;
6020 IF T13%=3 THEN LPRINT USING "#.###";WF4!;
6030 IF T13%=3 THEN LPRINT ZR1;
6040 LPRINT ZB;"      ";ZB;
6050 IF T14%=0 THEN LPRINT ZF;
6060 IF T14%=1 THEN LPRINT ZS3;

```



```

7055 IF A$="E" OR A$="e" THEN END
7060 IF A$="O" OR A$="o" GOTO 7090
7070 PRINT ZD1
7080 INPUT TITLES
7090 RETURN
7100 REM
7110 REM
7120 REM THIS IS THE BEGINNING OF THE SCREEN DISPLAY OUTPUT ROUTINE
7130 PRINT "[ _____]"
7140 PRINT "[ RESULTS ]"
7150 PRINT "[ Max bend stress top main flange: ";;PRINT USING "#####.##";BDSTR1!;;PRINT " PSI ["
7160 PRINT "[ Max bend stress bot main flange: ";;PRINT USING "#####.##";BDSTR2!;;PRINT " PSI ["
7170 IF ANALYSIS$="FALSE" GOTO 7190
7180 PRINT "[ Design bend stress main flanges: ";;PRINT USING "#####.##";ALMNFLBD!;;PRINT " PSI ["
7190 IF TF3!=0! THEN GOTO 7210
7200 PRINT "[ Max bend stress top aux flange: ";;PRINT USING "#####.##";BDSTR3!;;PRINT " PSI ["
7210 IF TF4!=0! THEN GOTO 7260
7220 PRINT "[ Max bend stress bot aux flange: ";;PRINT USING "#####.##";BDSTR4!;;PRINT " PSI ["
7230 IF TF3!=0! AND TF4!=0! GOTO 7260
7240 IF ANALYSIS$="FALSE" GOTO 7260
7250 PRINT "[ Design bend stress aux flanges: ";;PRINT USING "#####.##";ALAXFLBD!;;PRINT " PSI ["
7260 IF ECW!=0! THEN GOTO 7310
7270 PRINT "[ Max bend stress top center web: ";;PRINT USING "#####.##";BDSTR5!;;PRINT " PSI ["
7280 PRINT "[ Max bend stress bot center web: ";;PRINT USING "#####.##";BDSTR6!;;PRINT " PSI ["
7290 IF ANALYSIS$="FALSE" GOTO 7310
7300 PRINT "[ Design bend stress center web: ";;PRINT USING "#####.##";ALCNWBBD!;;PRINT " PSI ["
7310 IF EOW!=0! THEN GOTO 7360
7320 PRINT "[ Max bend stress top outer webs: ";;PRINT USING "#####.##";BDSTR7!;;PRINT " PSI ["
7330 PRINT "[ Max bend stress bot outer webs: ";;PRINT USING "#####.##";BDSTR8!;;PRINT " PSI ["
7340 IF ANALYSIS$="FALSE" GOTO 7360
7350 PRINT "[ Design bend stress outer webs: ";;PRINT USING "#####.##";ALOTWBBD!;;PRINT " PSI ["
7360 IF TW1!=0! THEN GOTO 7400
7370 PRINT "[ Max shear stress center web : ";;PRINT USING "#####.##";CSHRSTR!;;PRINT " PSI ["
7380 IF ANALYSIS$="FALSE" GOTO 7400
7390 PRINT "[ Design shear stress center web : ";;PRINT USING "#####.##";ALCNWBSH!;;PRINT " PSI ["
7400 IF TW2!=0! THEN GOTO 7420
7410 PRINT "[ Max shear stress outer webs: ";;PRINT USING "#####.##";OSHRSTR!;;PRINT " PSI ["
7420 IF ANALYSIS$="FALSE" GOTO 7431
7425 IF TW2!=0! THEN GOTO 7431
7430 PRINT "[ Design shear stress outer webs: ";;PRINT USING "#####.##";ALOTWBSH!;;PRINT " PSI ["
7431 IF AREA3!=0! GOTO 7434
7432 PRINT"[ The shear stress between top ["
7433 PRINT"[ main and top aux flanges: ";;PRINT USING "#####.##";SHRFLO3!;;PRINT" PSI ["
7434 IF AREA4!=0! GOTO 7440
7435 PRINT"[ The shear stress between bot ["
7436 PRINT"[ main and bot aux flanges: ";;PRINT USING "#####.##";SHRFLO4!;;PRINT" PSI ["
7440 IF ANALYSIS$="FALSE" GOTO 7500
7450 PRINT "[ For bending the";MAX1$;"governs ["
7460 IF TW1!>0! OR TW2!>0! THEN PRINT "[ For shear";MAX2$;"governs ["
7470 PRINT"[ The max allowable moment equals ";;PRINT USING "#####.##";MOM!;;PRINT" inch*pounds ["
7480 IF TW1!>0! OR TW2!>0! THEN PRINT "[ The max allowable shear equals ";:
PRINT USING "#####.##";SHR!;;PRINT " pounds ["
7490 GOTO 7520
7500 PRINT"[ Applied moment equals ";;PRINT USING "#####.##";MOM!;;PRINT" inch*pounds ["
7510 PRINT"[ Applied shear equals ";;PRINT USING "#####.##";SHR!;;PRINT" pounds ["
7520 PRINT "[ The moment of inertia of the entire ["
7530 PRINT "[ section with respect to the stiffness ["
7540 PRINT "[ of the main flanges equals: ";;PRINT USING "#####.##";MI7!;;PRINT "(inch**4) ["

```



```

7550 PRINT "[\////////////////////////////////////]"
7560 RETURN
7570 REM
7580 REM
7590 REM THIS IS THE END OR RECYCLE QUESTION ROUTINE
7600 PRINT "[_____]"
7610 PRINT "[    If you want to end program, then type an E;    ]"
7620 PRINT "[    If you want to recycle entire program, then type an R;  ]"
7630 PRINT "[    If you want to reuse geometry but reenter          ]"
7640 PRINT "[    new loads, then type a G;                               ]"
7670 PRINT "[\////////////////////////////////////]"
7680 AS=INKEY$:IF AS="" THEN 7680
7690 IF AS<>"r" AND AS<>"R" AND AS<>"G" AND AS<>"g" AND AS<>"w" AND AS<>"W" AND AS<>"e" AND AS<>"E" THEN GOTO 7600
7705 IF AS="E" OR AS="e" THEN END
7710 RETURN

```

DOWNWASH AT TAIL DUE TO CIRCULATORY FLOW AT WING

Max Chernoff -- March 1993

Tailplanes work at incidences which can be altered appreciably by tilting of the relative wind due to large downward induced velocity components. This change is reflected by the variation of the downwash angle which appears as the derivative :

$$d\varepsilon/d\alpha$$

which is the rate of change of the downwash angle with the relative angle of attack of the wing.

The part that can be evaluated is that due to the circulatory flow about the wing. Since spanwise variation in circulation is usually very close to an elliptical distribution, one can reasonably represent it by a bound vortex of span = $\pi / 4$ times the total span and then the circulation is represented by a bound vortex and two semi-infinite ones. The effect on the tail can then be determined by special application of the Biot-Savart law. The basic derivation is shown in the reference.

Much of the derivation below appears in the reference but is shown to illustrate what went into the program. For a bound vortex, the induced velocity at a point is:

$$w = K (2 \sin \beta) / (4 \pi x)$$

and for the semi-infinite vortices it is :

$$w = 2 K (1 + \cos \beta) / (4 \pi s)$$

where :

K = circulation

x = distance from wing to point at tail

s = semispan time $\pi/4$

β = angle between semi-infinite vortex and line from end of bound vortex and point on tail

The total downwash is the sum of these two. However, the value of the angle :

β is predicated by :

$$s = \cot \beta \text{ and } s = \pi/4 \text{ times semi-span}$$

The resultant downwash velocity normal to the plane becomes then:

$$w = K (1 + \sec \beta) / 2 \pi s$$

But since the semi-span value , **b** , is equal to $4 / \pi s$, and for an elliptical distribution the circulation is :

$$K = CL V S / (\pi b)$$

where :

CL = lift coefficient

V = velocity

S = area

The downwash angle is:

$$\varepsilon = \{ (2 CL V S) / (\pi^3 S^2 V) \} (1 + \sec \beta)$$

$$= \frac{8 CL}{\pi^3 (AR)} (1 + \sec \beta) \quad \text{where } AR = \text{aspect ratio}$$

The desired derivative can then be determined because :

$$d\epsilon / d\alpha = d\alpha / dCL \text{ times } d\epsilon / dCL$$

and finally :

$$\frac{d\epsilon}{d\alpha} = \frac{8 C_{L\alpha}}{\pi^3 (AR)} (1 + \sec \beta)$$

Modification for separation of planes is just a matter of geometry as the vector component normal to the tail surface is the only one that matters. If the distance vertically between the center of the wing and tail is h then if the angle is:

$$\arctan (h/x) = \theta \text{ then } x = h / \cos \theta$$

and the component velocity is then predicated by the value of :

$$\cos \theta$$

Similarly the effect of the dihedral angle, ϕ , is by the cosine of that angle.

Finally one can modify the above expression by :

$$x = h / \cos \theta$$

$$\frac{d\epsilon}{d\alpha} = \frac{d\epsilon}{d\alpha} \cos \theta \cos \phi$$

and for the planar case all cosine values are equal to unity.

The listing of the program shown was written in BASIC and format predicated by the utility Source Print. Some examples of output are shown for varying fuselage lengths for F1A Class Glider by Makarov as shown in NFFS 25th Annual Report 1992. It is evident for a high aspect ratio wing downwash effects are trivial. For low aspect ratio wings and short fuselages the effects are much larger.

It is acknowledged that there are other contributions to downwash velocity as noted in Hoerner's volume on lift but this is the only component that can be represented analytically. It may be the major portion due to the relatively slim fuselages and large ratio of wing span to tail span used.

REFERENCE:

"Aerodynamics for Engineering Students",
E. L. Houghton and N. B. Carruthers
published by Edward Arnold (London), 1982

PROGRAM LISTING (QUICK BASIC)

```

1
2
3     REM PROGRAM TO GENERATE VALUE OF DOWNWASH AT TAIL DUE TO
4     REM EFFECTS OF CIRCULATION ON WING. BIOT-SAVARD LAW USED TO DETERMINE
5     REM DOWNWASH VELOCITY. BOUND VORTEX USED FOR EVALUATION WITH ASSUMPTION
6     REM THAT SPANWISE DISTRIBUTION IS ELLIPTICAL. THE FINITE VORTEX IS EQUAL
7     REM IN SPAN TO PI/4 TIMES THE ACTUAL SPAN AND BOUNDED BY TWO SEMI-INFINITE
8     REM VORTICES. EFFECT OF TAIL POSITION AND DIHEDRAL ARE INCLUDED
9
10    DEFINT  I-L
11
12    PI = 3.14159
13    PI3 = PI^3
14    RADCON = PI / 180!
15  START:
16    LPRINT "-----"
17    LPRINT
18    INPUT "SPAN OF WING", S
19    INPUT "AREA OF WING", A
20    INPUT "AVERAGE dCL/dALPHA (PER DEGREE) "; CLA
21    B = S / 2!
22    AR = S^2 / A
23    P = 8! * CLA / (PI3 * AR)
24    LPRINT "SPAN= "; S; " AREA= "; A; " CLA= "; CLA
25    LPRINT "ASPECT RATIO= "; AR
26    PRINT "SPAN= "; S; " AREA= "; A; " CLA= "; CLA
27    PRINT "'ASPECT RATIO= "; AR
28    LPRINT
29  REPEAT:
30    LPRINT "*****"
31    CT = 1!
32    CP = 1!
33    INPUT "DISTANCE FROM QUARTER CHORD TO L.E. OF TAIL ", X
34    IF (X <= 0!) THEN X = .1
35    LPRINT "DISTANCE FROM QUARTER CHORD TO TAIL = "; X
36    PRINT "DISTANCE FROM QUARTER CHORD TO TAIL = "; X
37    INPUT "IS TAIL ABOVE OR BELOW WING CENTER (Y/N) ", H$
38    IF (UCASE$(H$) = "N") THEN GOTO DIH
39    INPUT "VERTICAL SEPARATION OF WING AND TAIL ", HE
40    LPRINT "VERTICAL SEPARATION OF WING AND TAIL ="; HE
41    PRINT "VERTICAL SEPARATION OF WING AND TAIL = "; HE
42    HE = ABS(HE)
43    THET = ATN(HE / X)
44    CT = COS(THET)
45    X = X / CT
46  DIH:
47    INPUT "IS THERE DIHEDRAL IN WING (Y/N) ", D$
48    IF (UCASE$(D$) = "N") THEN GOTO EPS
49    INPUT "EQUIVALENT DIHEDRAL OF WING IN DEGREES ", PHI
50    LPRINT
51    LPRINT "EQUIVALENT DIHEDRAL ANGLE = "; PHI
52    PRINT "EQUIVALENT DIHEDRAL ANGLE = "; PHI
53    CP = COS(PHI * RADCON)
54  EPS:

```

```

55      BETA = ATN(.25 * PI * B / X)
56      DEDALP = P * (1! + 1! / COS(BETA)) * CT * CP
57      LPRINT "dEPS/dALPHA = "; DEDALP
58      PRINT "dEPS/dALPHA = "; DEDALP
59      INPUT "USE SAME BASIC GEOMETRY WITH NEW VARIATIONS (Y/N) ", P$
60      IF (UCASE$(G$) = "Y") THEN GOTO REPEAT
61      INPUT "NEW BASIC GEOMETRY (Y/N) ", G$
62      IF (UCASE$(G$) = "Y") THEN GOTO START
63      LPRINT "END OF RUN"
64      PRINT "END OF RUN"
65

```

SAMPLE OF PROGRAM OUTPUT

```

SPAN=    92  AREA=  468  CLA=  .095
ASPECT RATIO=  18.08547

```

```

*****
DISTANCE FROM QUARTER CHORD TO TAIL =  28

EQUIVALENT DIHEDRAL ANGLE =  6
dEPS/dALPHA =  3.548201E-3
-----

```

```

SPAN=    92  AREA=  468  CLA=  .095
ASPECT RATIO=  18.08547

```

```

*****
DISTANCE FROM QUARTER CHORD TO TAIL =  28
VERTICAL SEPARATION OF WING AND TAIL =  8

EQUIVALENT DIHEDRAL ANGLE =  6
dEPS/dALPHA =  3.361201E-3
*****
DISTANCE FROM QUARTER CHORD TO TAIL =  24

```

```

EQUIVALENT DIHEDRAL ANGLE =  6
dEPS/dALPHA =  3.783789E-3
*****
DISTANCE FROM QUARTER CHORD TO TAIL =  20

```

```

EQUIVALENT DIHEDRAL ANGLE =  6
dEPS/dALPHA =  4.13088E-3
*****
DISTANCE FROM QUARTER CHORD TO TAIL =  16

```

```

EQUIVALENT DIHEDRAL ANGLE =  6
dEPS/dALPHA =  4.676511E-3
*****
DISTANCE FROM QUARTER CHORD TO TAIL =  12

```

```

EQUIVALENT DIHEDRAL ANGLE =  6
dEPS/dALPHA =  5.623903E-3
*****

```

ON WING LOAD COMPUTATION

Max Chernoff - March 1992

In the application of lifting line analysis, a line of vortices on the quarter chord is assumed to represent the wing and which are designated as the circulation. For subsonic conditions and moderate to high aspect ratios, the resulting air loads distribution are adequate with the exception of effects of tip vortices which generally act to reduce drag than to have a great effect on the air load distribution. Input data consists of primary geometric data, Reynolds number, total air load and density of air under average conditions. From this are derived the total lift coefficient and velocity based upon spanwise variation in circulation.

Equations for analysis are as follows:

$$V = \frac{Re}{6360 \times C_{ave}}$$

where V = velocity in fps

Re = Reynolds number

C_{ave} = average chord in feet

$$L = \text{weight(lbs)} \times \text{load factor}$$

where load factor = 1 for level flight
or greater

$$C_L = \frac{2L}{\rho V^2 A}$$

where C_L = lift coefficient

A = area in square feet

ρ = density of air

= .002378 lbs.ft.⁻⁴sec.²

$$L = \rho V \int_{-s}^s K dy$$

where s = semi-span coordinate dimension

K = circulation

$$D = \rho \int_{-s}^s w K dy$$

where D = induced drag

w = downwash at 3/4 chord

For analysis purposes the symmetric loading model is to be considered here. Utilizing a lifting load program, various configurations were analyzed considering the following variations:

1. taper ratio
2. flap deflection
3. washout variation
4. washin variation
5. airfoil variation along semi-span

with the result that in all cases spanwise variation in circulation closely approximated an elliptical form. Hence a variation in lift being described as elliptical is suitable for prediction of loads and variation in shear and bending moment. The resulting expressions would then be in closed form not requiring numerical integration.

It follows that:

$$K = K_0 \sqrt{1 - \left(\frac{y}{s}\right)^2}$$

where K_0 = circulation at mid-span

from which:

$$\begin{aligned} L &= \rho V K_0 \int_{-s}^s \sqrt{1 - \left(\frac{y}{s}\right)^2} dy \\ &= \rho V K_0 \pi \frac{s}{2} \end{aligned}$$

$$\text{and then } K_0 = \frac{2L}{\rho V \pi s} = \frac{C_L V A}{\pi s}$$

and then induced drag finally is :

$$\begin{aligned} D_i &= \int_{-s}^s \rho \frac{K_0}{4s} K_0 \sqrt{1 - \left(\frac{y}{s}\right)^2} dy \\ &= \frac{\pi}{8} \rho K_0^2 = C_{Di} \frac{\rho}{2} V^2 A \end{aligned}$$

where C_{Di} = induced drag coefficient

From equation for K_0 :

$$C_{Di} = \frac{C_L^2}{\pi AR} \quad \text{where } AR = \text{aspect ratio} = \frac{4s^2}{A}$$

If the plan form is elliptical, the local C_L is constant since the chord varies in the same way as predicted by the plan form. In that case the local profile drag coefficient would also be constant over the span. The coefficient is then

C_{DP} which is derivable from airfoil data. In any case the value of the profile drag coefficient based upon the total lift coefficient if it is in the mid range of the curves. The total drag would then be the summation of both effects as follows:

$$\text{DRAG} = (C_{Di} + C_{DP}) \frac{\rho}{2} V^2 A$$

For shear and bending moment values, integration from a lower bound of a reference station to the tip is now done. Using a change in variables:

$$z = y/s$$

and the derived expression for K_0 , the shear value is :

$$S = C_L \left(\frac{\rho V^2 A}{\pi} \right) \int_z^1 \sqrt{1-z^2} dz = \frac{2L}{\pi} \int_z^1 \sqrt{1-z^2} dz$$

Evaluating the integral and using the arctan function instead of the arcsin function because the arctan function exists in computer languages, the shear value in lbs. S, is :

$$S = \frac{2L}{\pi} \left(\frac{\pi}{4} - \frac{z}{2} \sqrt{1-z^2} - \frac{1}{2} \arctan \frac{z}{\sqrt{1-z^2}} \right)$$

For $z=0$, $S = L/2$ which is correct. At each station the torsion is the shear value times the distance from the quarter chord to the shear center.

Similarly for the bending moment using the same change in variable:

$$M = \frac{2Ls}{\pi} \int_z^1 z \sqrt{1-z^2} dz$$

Evaluating the integral, the bending moment in ft.lbs., M, is as follows:

$$M = \frac{2Ls}{3\pi} (1-z^2)^{\frac{3}{2}}$$

The root bending moment, $\frac{2Ls}{3\pi}$, when divided by the semi-span value gives the mean chord location.

One approach is to input the Reynold's number, then to derive the velocity from which the lift and drag coefficients are derived based upon input value of the load factor. Another approach is to input the velocity, then compute Reynold's number and then based upon an assumed lift coefficient value equal to unity from which the load factor is computed. The later method may be more realistic in terms of observed values especially for circle tow launches. For example a F1A class Nordic design by Sergio Makarov was examined for ranges in velocities with the following results :

<u>VELOCITY</u>	<u>LOAD FACTOR</u>
50	8.8
60	12.6
70	17.1
80	22.4

which agree with observed values.

A program was developed using the BASIC language. Some results of computations are included.

References used are:

- 1. "Aerodynamics for Engineering Students", E. L. Houghton and N. B. Carruthers, Edward Hutton(Publishers)Ltd., Third Edition, 1982**
- 2. "A Computer Program for Lifting Line Analysis for Symmetric Air Load Distribution",Max Chernoff, 1989**
- 3. "Handbook of Mathematics",I. N. Bronshtein, K. A. Semendyayev, English Translation, Van Nostrand Reinhold Company,1978**
- 4."Twenty -Fifth Annual Report 1992", National Free Flight Society**

PROGRAM LISTING (QUICK BASIC)

```

REM   Program developed by Max Chernoff to be used for estimating wing loads
REM   and resulting shears and bending moments for stress analysis. Air load
REM   distribution is elliptical and total lift coefficient is set equal to
REM   one whereupon loads are dependent upon velocity and weight of vehicle.
REM   The load factor is dependent upon speed of aircraft. Shear and bending
REM   moment values are calculated at 21 equally spaced stations on the
REM   semi-span included root and tip stations.

```

```
DEFINT I-N
```

```
DECLARE SUB geome ()
```

```
DECLARE SUB geomn ()
```

```
DECLARE SUB compre ()
```

```
DECLARE SUB compv ()
```

```
DECLARE SUB c11 ()
```

```
COMMON SHARED wt, ws, wa, ar, wl, v, re, pi, rho
```

```
ptout$ = " ##.#### "
```

```
pi = 3.14592654#
```

```
rho = .002378
```

```
start:
```

```

LPRINT CHR$(12)           'top of page at printer
LPRINT "-----START OF RUN-----"
LPRINT
PRINT "two title cards for description of aircraft"
INPUT "first title card", T1$
PRINT T1$
LPRINT T1$
INPUT "second title card", T2$
PRINT T2$
LPRINT T2$
gnd = 1
INPUT "is input data in metric system (y/n) ?", g$
IF (UCASE$(g$) = "Y") THEN
    gnd = 2
END IF
IF (gnd = 1) THEN CALL geome
IF (gnd = 2) THEN CALL geomn
PRINT "WEIGHT (LBS) = "; wt
LPRINT "WEIGHT (LBS) = "; wt
PRINT "WING AREA (SQ.FT.) = "; wa
LPRINT "WING AREA (SQ.FT.) = "; wa
PRINT "WING SPAN (FT.) = "; ws
LPRINT "WING SPAN (FT.) = "; ws
ar = ws ^ 2 / wa
gv = 1
INPUT "input velocity instead of Re (y/n) ?", v$
IF (UCASE$(v$) = "Y") THEN gv = 2
IF (gv = 1) THEN CALL compre
IF (gv = 2) THEN CALL compv
CALL c11

```

```
repeat:
```

```
INPUT "more analysis for same configuration (y/n) ?", dec$
```

```

INPUT "go to top of page in printout (y/n) ?", pr$
IF (UCASE$(dec$) = "N") THEN GOTO more
IF (UCASE$(pr$) = "Y") THEN LPRINT CHR$(12)
IF (UCASE$(dec$) = "Y" AND gv = 1) THEN CALL compre
IF (UCASE$(dec$) = "Y" AND gv = 2) THEN CALL compv
IF (UCASE$(dec$) = "Y") THEN CALL c11
GOTO repeat

more:
INPUT " try another configuration (y/n) ?", con$
IF (UCASE$(con$) = "Y") THEN GOTO start
PRINT " -----END OF RUN-----"
END

SUB c11
REM computation of shear and bending moment values
DIM z(21), sh(21), bm(21), y(21)
s = ws / 2
cons = 2 * w1 / pi
conn = cons * s / 3
sh(0) = w1 / 2
sh(20) = 0
bm(0) = conn
bm(20) = 0
y(0) = 0
y(20) = s
FOR i = 1 TO 19
  z(i) = i * .05
  y(i) = z(i) * s
  sh(i) = pi / 4 - z(i) * .5 * SQR(1 - z(i) ^ 2) - .5 * ATN(z(i) / SQR(1 - z(i) ^ 2))
  sh(i) = cons * sh(i)
  bm(i) = conn * (1 - z(i) ^ 2) ^ 1.5
NEXT i
PRINT " y(ft)      shear(lbs)      bending moment(ft.lbs.)"
LPRINT " y(ft)      shear(lbs)      bending moment(ft.lbs.)"
FOR i = 0 TO 20
  PRINT y(i), sh(i), bm(i)
  LPRINT y(i), sh(i), bm(i)
NEXT i
END SUB

SUB compre
REM input in reynolds no. value
INPUT "VALUE OF REYNOLDS NO. ? ", re
cave = wa / ws
v = re / (6360 * cave)
w1 = rho * v ^ 2 * wa / 2
wlf = w1 / wt
cdi = 1! / (pi * ar)
cdp = 0
INPUT "INPUT VALUE OF PROFILE DRAG COEFF. (Y/N) ? ", d$
IF (UCASE$(d$) = "Y") THEN INPUT "PROF. DRAG COEFF ? ", cdp
drag = (cdi + cdp) * rho * v ^ 2 * wa / 2
PRINT "Reynolds No = ", re
LPRINT "Reynolds No = ", re
PRINT "Vel in FPS = ", v
LPRINT "Vel in FPS = ", v
PRINT "Load Factor = ", wlf
LPRINT "Load Factor = ", wlf

```

```

        PRINT "Drag in Lbs. = ", drag
        LPRINT "Drag in Lbs. = ", drag
END SUB

SUB compv
REM input by velocity value
    INPUT "VELOCITY IN FPS ? ", v
    cave = wa / ws
    re = 6360 * cave * v
    wl = rho * v ^ 2 * wa / 2
    wlf = wl / wt
    cdi = 1 / (pi * ar)
    cdp = 0
    INPUT "INPUT VALUE OF PROFILE DRAG COEFF. (Y/N) ? ", d$
    IF (UCASE$(d$) = "Y") THEN INPUT "PROF. DRAG COEFF ? ", cdp
    drag = (cdi + cdp) * rho * v ^ 2 * wa / 2
    PRINT "Reynolds No = ", re
    LPRINT "Reynolds No = ", re
    PRINT "Vel in FPS = ", v
    LPRINT "Vel in FPS = ", v
    PRINT "Load Factor = ", wlf
    LPRINT "Load Factor = ", wlf
    PRINT "Drag in Lbs. = ", drag
    LPRINT "Drag in Lbs. = ", drag
END SUB

SUB geome
REM input in fps
    INPUT "WEIGHT IN LBS. ?", wt
    INPUT "WING SPAN IN FT. ?", ws
    INPUT "WING AREA IN SQ.FT. ?", wa
END SUB

SUB geommm
REM input in cgs
    INPUT "WEIGHT IN GRAMS ? ", wt
    wt = .0022046 * wt
    INPUT "WING SPAN IN MM ? ", ws
    ws = ws / 304.8
    INPUT "WING AREA IN DM(SQUARED) ? ", wa
    wa = wa / 9.29
END SUB

```

F1A CLASS GLIDER

SERGE MAKAROV

WEIGHT (LBS) = .9

WING AREA (SQ.FT.) = 3.2

WING SPAN (FT.) = 7.8

Reynolds No = 130461.5

Vel in FPS = 50

Load Factor = 10.56889

Drag in Lbs. = .1590318

y(ft)	shear(lbs)	bending moment(ft.lbs.)	
0	4.756	7.861341	
.195	4.453767	7.83188	
.39	4.152291	7.743717	
.585	3.852335	7.597519	
.78	3.554675	7.39441	
.975	3.260103	7.135979	
1.17	2.969437	6.82431	
1.365	2.683528	6.462006	
1.56	2.403273	6.052232	
1.755	2.129622	5.598771	
1.95	1.863597	5.106091	
2.145	1.606309	4.579446	
2.34	1.35899	4.025007	
2.535	1.123027	3.450044	
2.73	.9000201	2.863202	
2.925	.6918669	2.274908	
3.12	.5009126	1.69805	
3.315	.3302145	1.149188	
3.51	.184115	.6510687	
3.705	6.981459E-02		.2393336
3.9	0	0	

Reynolds No = 156553.8

Vel in FPS = 60

Load Factor = 15.2192

Drag in Lbs. = .2290058

y(ft)	shear(lbs)	bending moment(ft.lbs.)
0	6.84864	11.32033
.195	6.413424	11.27791
.39	5.979299	11.15095
.585	5.547363	10.94043
.78	5.118732	10.64795
.975	4.694548	10.27581
1.17	4.275989	9.827005
1.365	3.864281	9.305287
1.56	3.460714	8.715214
1.755	3.066656	8.062229
1.95	2.683579	7.35277
2.145	2.313085	6.594402
2.34	1.956946	5.796009
2.535	1.617159	4.968062
2.73	1.296029	4.12301
2.925	.9962883	3.275867
3.12	.7213141	2.445191
3.315	.4755089	1.65483
3.51	.2651256	.9375389
3.705	.100533	.3446404
3.9	0	0

Reynolds No =		182646.2
Vel in FPS =	70	
Load Factor =		20.71502
Drag in Lbs. =		.3117024
y(ft)	shear(lbs)	bending moment(ft.lbs.)
0	9.32176	15.40823
.195	8.729383	15.35048
.39	8.13849	15.17768
.585	7.550577	14.89114
.78	6.967163	14.49304
.975	6.389801	13.98652
1.17	5.820096	13.37565
1.365	5.259716	12.66553
1.56	4.710416	11.86237
1.755	4.174059	10.97359
1.95	3.652649	10.00794
2.145	3.148365	8.975714
2.34	2.663621	7.889012
2.535	2.201133	6.762085
2.73	1.764039	5.611875
2.925	1.356059	4.458818
3.12	.9817886	3.328177
3.315	.6472204	2.252408
3.51	.3608654	1.276095
3.705	.1368366	.4690939
3.9	0	0

Reynolds No =		208738.5
Vel in FPS =	80	
Load Factor =		27.05636
Drag in Lbs. =		.4071214
y(ft)	shear(lbs)	bending moment(ft.lbs.)
0	12.17536	20.12503
.195	11.40164	20.04961
.39	10.62986	19.82391
.585	9.861979	19.44965
.78	9.099968	18.92969
.975	8.345863	18.2681
1.17	7.601757	17.47023
1.365	6.869833	16.54273
1.56	6.15238	15.49371
1.755	5.451833	14.33285
1.95	4.770807	13.07159
2.145	4.112151	11.72338
2.34	3.479015	10.30402
2.535	2.87495	8.832111
2.73	2.304051	7.329796
2.925	1.771179	5.823763
3.12	1.282336	4.347007
3.315	.8453492	2.941921
3.51	.4713343	1.666736
3.705	.1787253	.612694
3.9	0	0

R/C SAILPLANE

GENERIC

WEIGHT (LBS) = 6

WING AREA (SQ.FT.) = 6.5

WING SPAN (FT.) = 10

Reynolds No = 82680

Vel in FPS = 20

Load Factor = .5152333

Drag in Lbs. = .0638734

y(ft)	shear(lbs)	bending moment(ft.lbs.)	
0	1.5457	3.275558	
.25	1.447474	3.263283	
.5	1.349494	3.226548	
.75	1.252009	3.165632	
1	1.155269	3.081004	
1.25	1.059533	2.973324	
1.5	.9650668	2.843462	
1.75	.8721467	2.692502	
2	.7810638	2.521763	
2.25	.6921272	2.332821	
2.5	.6056689	2.127538	
2.75	.5220504	1.908102	
3	.4416718	1.677086	
3.25	.3649839	1.437518	
3.5	.2925065	1.193001	
3.75	.2248567	.947878	
4	.1627966	.7075205	
4.25	.1073197	.4788282	
4.5	5.983737E-02		.2712786
4.75	2.268974E-02		9.972233E-02
5	0	0	

Reynolds No = 206700

Vel in FPS = 50

Load Factor = 3.220208

Drag in Lbs. = .3992087

y(ft)	shear(lbs)	bending moment(ft.lbs.)
0	9.660625	20.47224
.25	9.046714	20.39552
.5	8.43434	20.16593
.75	7.825056	19.7852
1	7.220433	19.25627
1.25	6.622083	18.58328
1.5	6.031667	17.77164
1.75	5.450917	16.82814
2	4.881649	15.76102
2.25	4.325795	14.58013
2.5	3.785431	13.29711
2.75	3.262815	11.92564
3	2.760449	10.48179
3.25	2.281149	8.984488
3.5	1.828166	7.456254
3.75	1.405354	5.924237
4	1.017479	4.422004
4.25	.6707482	2.992676
4.5	.3739835	1.695491
4.75	.1418109	.6232646
5	0	0

THE ADVANCED PLANK (AP 86) PLANFORM

by Denis W. Oglesby

Denis has written about his experiences with a new design concept for "Plank" type flying wings - optimized for thermal soaring. His original purpose was to develop a design that would "simultaneously maintain near elliptical span loading at all trim settings of the elevator. His original work was published in England. Now after flying a small (52 inch span) example of the concept which he called "A Clockwork Kestrel" he has developed his ideas further. However, at the time we last corresponded, Denis had not yet built the full size version.

The root airfoil proposed is a version of the Eppler 186 which has been thinned (about its camber line) to nine percent. Its angle of incidence should be +0.14 degrees relative to the untwisted Eppler 182 wing panels. Denis calculates that when the E-182 is trimmed to fly at its design lift coefficient of 0.6, the entire wing should be operating at a lift coefficient of 0.5. The design elevator settings are 5.2 degrees up for slow speed and 5.2 down for a vertical dive.

In the notes that were sent with the drawing, there is the recommendation to size the AP 86 by starting with the wing of an equivalent conventional sailplane. Design the AP with the same span and with the same flying weight as the conventional model. Then make the value of "c" (the root dimension of the E-182 panel) equal to 1.67 times the root chord of the conventional design. For a more aerobatic version, make "c" equal to 1.3 times the conventional wing root chord.

The ailerons are to be located outboard on the E-182 panels, and the unusual double triangle elevator surface is at the rear of the center section. The small keel is there primarily to land on and to provide the model flyer with a hand hold.

In flying the "Clockwork Kestrel" Denis found the elevator surface to be too small and he solved some problems with pitch control by increasing its chord at the centerline by 50 percent. This modification combined with lower surface turbulators just ahead of the elevator gave the improvement he was looking for. He has also decided that the upward only ailerons are not as good as ordinary aileron operation combined with zero differential. On the "Kestrel" he found

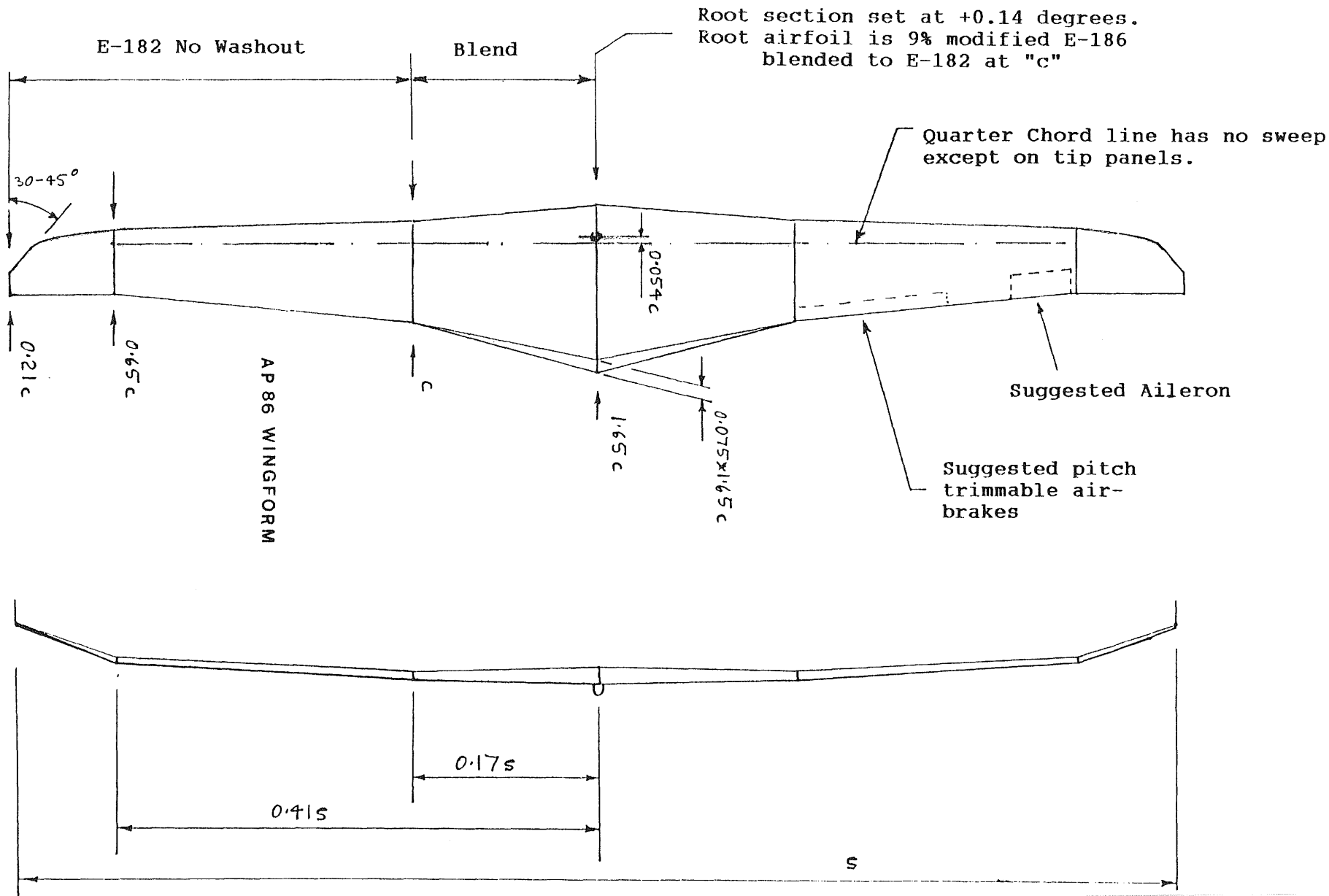
that the tip fins had little value and he removed them. During discussions with Rheinhard Werner, he also found that a tendency of the plane to wander into a roll can be reduced by placing lower surface turbulators on the wings.

Denis wrote that he didn't think that readers would find the 14 pages of algebra he used (to bring together the elliptical lift distribution and longitudinal balance) would be interesting to SoarTech readers. What do you think? Either way, someone who wishes to build the high performance flying wing may beat Denis to it. You now have all the information required.

My own comments on the project are based on Denis complete notes and the previously published articles that he sent. first, this is an exciting concept, and I hope someone will follow up on it. I think that some of the control problems Denis experienced may be related to the small size and light weight of his prototype. Almost anywhere that he put turbulators on the plane seemed to help. The stability of these reflexed airfoils works against pitch control, and with such a small elevator working against so much reflex, it's no wonder that the plane had some pitch control problems.

He also had problems with roll that he never really solved. General Aero theory says that the span of a control surface is more important than its chord. (Of course you know that you have to be very careful about applying general theory to models!) When Gene Dees built his flying wing he made sure that he had plenty of both chord and span on his control surfaces. That worked well!

I might suggest making the ailerons about 20-22% of the local wing chord and increasing their span significantly. With computer radios, mixing the ailerons with elevator control to increase its effectiveness could also be a useful enhancement. Likewise, with no rudder to counteract adverse yaw, the upturned tips on the AP 86 might also work against good roll control. A builder could make them removable and adjust their dihedral with a series of different joiners to investigate this potential problem area. Or, he could just put a big ugly rudder on the rear of the centerline UGH! -- Herk.



E 186 modified

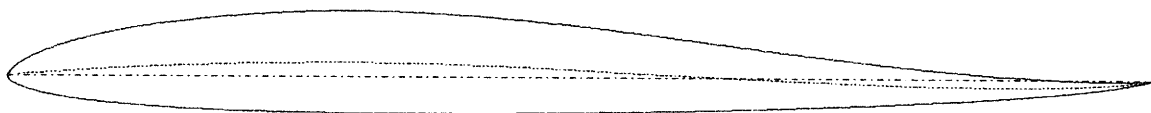
x	y	x	y	x	y	x	y
100.000	0.000	40.224	5.431	0.225	-0.415	59.681	-2.895
99.654	-0.024	35.529	5.696	1.046	-0.859	64.773	-2.746
98.619	-0.079	31.007	5.808	2.370	-1.305	69.702	-2.571
96.907	-0.124	26.677	5.765	4.187	-1.713	74.414	-2.371
94.552	-0.108	22.558	5.579	6.484	-2.076	78.854	-2.149
91.612	-0.003	18.678	5.278	9.244	-2.386	82.972	-1.910
88.154	0.199	15.079	4.880	12.444	-2.643	86.723	-1.654
84.239	0.498	11.800	4.399	16.054	-2.848	90.062	-1.389
79.936	0.893	8.874	3.850	20.040	-3.002	92.952	-1.115
75.314	1.375	6.330	3.244	24.360	-3.110	95.357	-0.830
70.447	1.932	4.191	2.598	28.968	-3.176	97.275	-0.526
65.412	2.549	2.475	1.927	33.815	-3.204	98.725	-0.243
60.283	3.200	1.196	1.257	38.847	-3.201	99.667	-0.059
55.138	3.860	0.367	0.607	44.007	-3.167	100.000	0.000
50.052	4.485	0.004	0.049	49.239	-3.105		
45.073	5.021	0.000	-0.012	54.483	-3.014		

62 coordinate points

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Moment coefficient c_{m_0} : 0.0560
 Zero lift angle α_0 : 1.29 °

Thickness: 9.00 %
 Rearw. pos. of max. thickness: 30.80 %
 Camber: 1.32 %
 Rearw. pos. of max. camber: 28.80 %



Categories: *Aerobatic soaring Tailless non swept*

Entwurf: Prof. Eppler
 Quelle: MTB 1/2

Thickness changed from 10.3 to 9.0 %

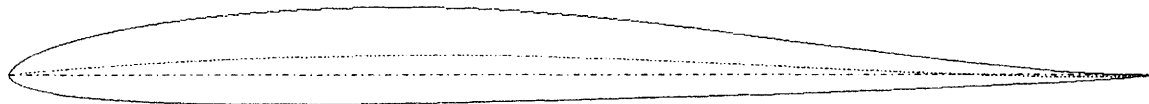
E 182

x	y	x	y	x	y	x	y
100.000	0.000	42.219	5.723	0.095	-0.275	58.563	-1.924
99.676	-0.003	37.464	5.902	0.718	-0.727	63.758	-1.757
98.709	-0.005	32.838	5.937	1.852	-1.158	68.800	-1.585
97.104	0.018	28.363	5.843	3.492	-1.542	73.631	-1.409
94.881	0.098	24.083	5.643	5.625	-1.866	78.195	-1.233
92.084	0.268	20.042	5.348	8.241	-2.127	82.438	-1.058
88.780	0.541	16.285	4.968	11.318	-2.327	86.311	-0.888
85.036	0.913	12.850	4.512	14.828	-2.468	89.769	-0.723
80.913	1.374	9.771	3.989	18.735	-2.554	92.769	-0.564
76.477	1.911	7.078	3.409	23.001	-2.590	95.276	-0.407
71.797	2.510	4.796	2.784	27.579	-2.582	97.272	-0.249
66.943	3.148	2.943	2.127	32.419	-2.536	98.752	-0.109
61.985	3.799	1.529	1.456	37.467	-2.457	99.681	-0.025
56.996	4.421	0.560	0.802	42.666	-2.351	100.000	0.000
52.016	4.967	0.048	0.216	47.956	-2.225		
47.080	5.408	0.000	0.000	53.275	-2.081		

62 coordinate points

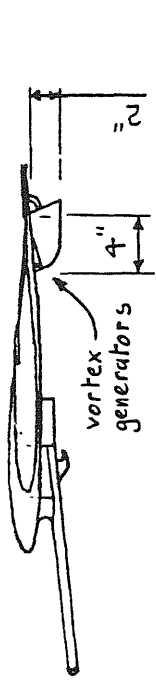
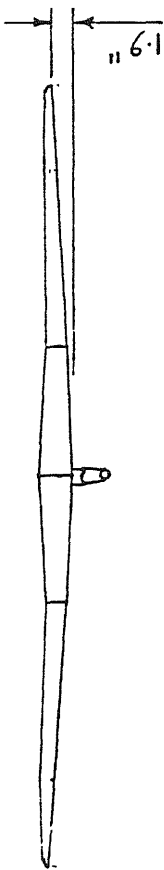
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Moment coefficient	cm_0 :	0.0080	Thickness:	8.47 %
Zero lift angle	α_0 :	-0.20 °	Rearw. pos. of max. thickness:	32.00 %
			Camber:	1.72 %
			Rearw. pos. of max. camber:	36.70 %



Categories: *Slope soaring* *Tailless swept*

Entwurf: Prof. Eppler
 Quelle: MTB 1/2, FMT 4/1971



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