HOW I MAKE WOOD PROPELLERS

WARNING!!

The author of this treatise is not an engineer, aeronautical, or otherwise. He does not claim origonality for any of the information contained in it. He does not claim that this is the only way propellers should be designed and carved, or that you should design or carve yours in this way. He has nothing to sell. No propellers. No plans for carving your own propellers. No plans for building his plane,"Die Fledermäus". He does not even have this book for sale.

He does profess to be an authority on a few things, however, but certainly not on writing books. He claims to be an authority on how his plane was built, how its engine was converted, how his propellers were designed and carved, how they worked, and how his plane flies. He'd ought to know. He has been the only person to fly it during the 540 times it has been flown except the first, and twice more fall. He designed, carved, and tested all of the propellers that have been flown on it.

Because his approach to the matter of propeller making seems to be at least somewhat different from that of others, he thought you might be interested.

He asks that you forgive his poor job of typing and proof reading, his bad spelling, his amateurish attempts at illustrating,and his crude examples of rustic humor. If you do not like his book he would gladly receive it back rather than to have you throw it into the garbage.

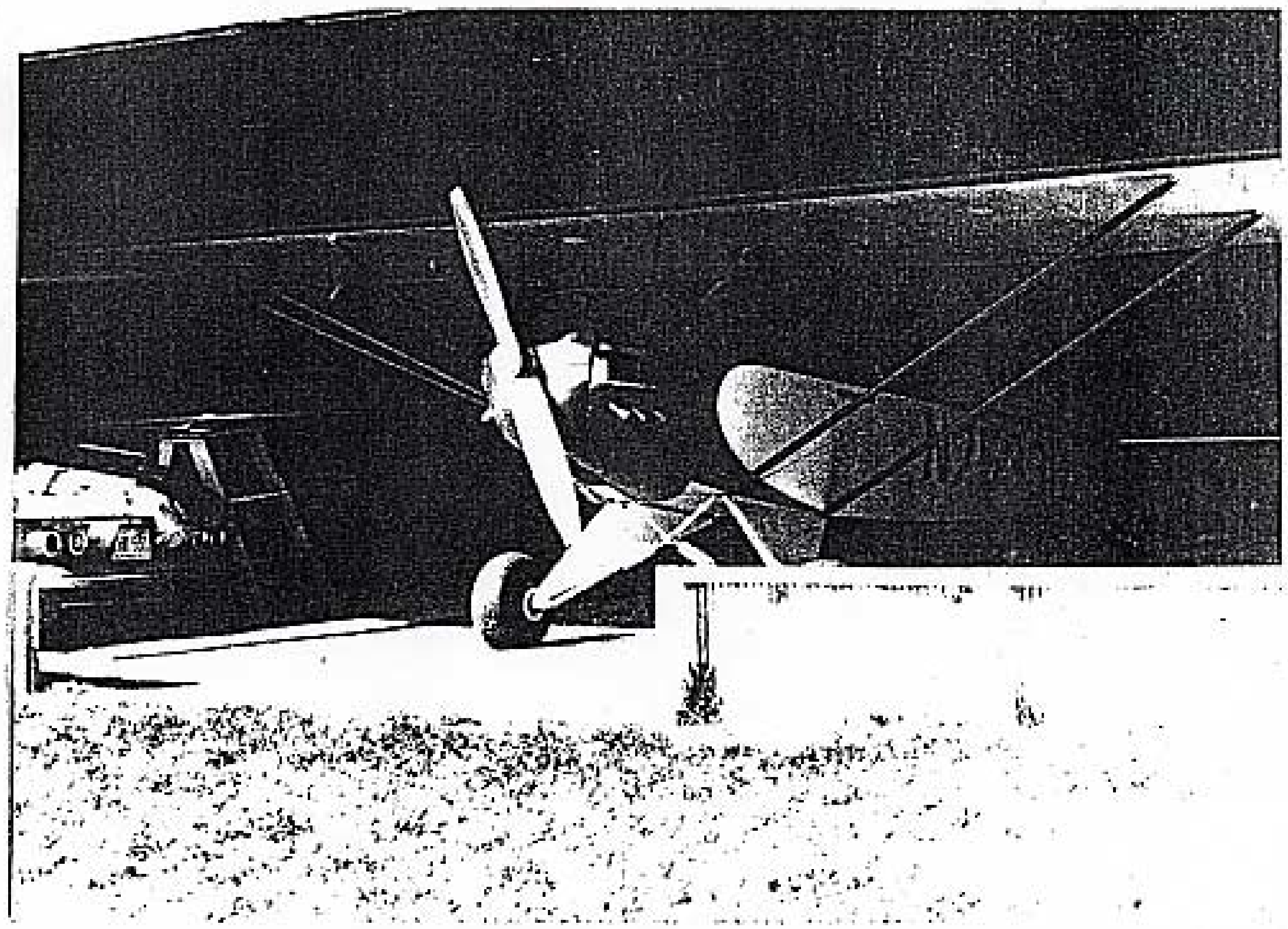
With these few remarks, I submit,
HOW I MAKE WOOD PROPELLERS.

E. Alvin Schubert

Author

August 7, 1984

How I Make Wood Propellers



by - Al Schubert

HOW I MAKE WOOD PROPELLERS

PREFACE

This book is not intended to be an exhaustive, polished scientific thesis on the design and fabrication of propellers for factory built certified aircraft. Nor is it aimed at the serious aeronautical student, even though it might give him a few good insights. Rather it is meant for the person who has always wanted to whittle a propeller for for his own homebuilt plane, but does not know how to go about it, nor who to ask for help. Perhaps he has a lower powered homebuilt, or even an ultralite which he has built that just does not seem to put out the performance the designer led him to expect of it. He suspects that his purchased propeller is at least part of the cause of it. He has paid a pretty good price for this one and hates to pay out that kind of money again for another that may work no better. He just wishes he knew how to carve one himself. He has been led by "authorities" to believe that the design and carving of propellers is a deap, dark science into which the amateur dare not stray. But they look so simple! When he built the plane he learned to weld, to glue, to laminate, to dope, and to work with sheet metal. Why can't he learn to carve a propeller? Perhaps then he could get his plane to perform like the seller of the plans promised it would. Anyway he certainly must have a little better takeoff and climb! There is also the person who is building something using some new or odd engine which to his knowlege, no one has used before.

This book does not claim to "tell all". It acknowleges that there are quite a few books on the subject written by other authors. A few of them are very rudimentary, but properly used, can lead one to a measure of success. Others are much more exhaustive and technical but may not necesarily be any more helpful. This author would advise one who wishes to carve his own propellers to obtain several of these other books and,along with this one, STUDY THEM, not just give them a "once over lightly". The would be carver must realize that one just does not understand all the things contained in them in an instant! It takes time and study before it all sinks in!

This book is written in a rather a free style rather than as a formal "text" book. Occasionally there are wisecracks and over and under statements for purposes of humor or emphasis. This book contains at

PREFACE (continued)

least part of the know how accumulated by the author during his more than fifty years of interest in the subject. It tries to speak to some of the phases and factors of propeller design and carving which many other books touch very lightly or not at all. It avoids complex formulas which, though they promise precise answers cannot deliver them if for no other reason than that the amatuer propeller designer does not have precise data to put into them. Consequently he cannot expect to get precise answers from them. The professional, though he may claim to, can hardly do much better. Thats why test pilots are employed. The many pictures and drawings have been included to illustrate a particular point the author is trying to make, as well as to give some idea of the scope of his experience and to entertain. A number of the author's more successful propeller designs have also been included.

This book shows how the author designs and makes individual hand produced experimental propellers for experimental aircraft. It does not show how to mass produce them.

He hopes that it might be of some use to you.

PREFACE (continued)

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PREFACE TO THE AUGUST 83 EDITION (continued)

would choose to buy their propellers and would not bother to learn to carve them themselves.

When I visited the shelter where propeller carving was being demonstrated I found that I had been mistaken. Whenever there was any-ome there to talk to them there would be a group wanting to learn. The two men working there looked as if they could use someone to spell them at least part of the time. I spent five afternoons at the booth and met many old friends and a number of celebrities including 3 or more professional carvers. Visitors at the demonstrations often asked how they could obtain a copy of my book. When I told them that it was not for sale many were visibly disappointed. I told those who seemed definitely to be interested in learning to carve propellers to write down their names and addresses and when I got home I would print up a quanity and send them one. By the final day I had a list of twenty-five. On it are a number who are presently advertising and producing propellers for sale.

I am sure that there is a lot of knowledge about propellers that has been discovered over the years that is not written down in any books. At least not in any form that the homebuilder can easily obtain or understand. Before the present homebuilding era began very few propeller designers were needed. There was no use for the home carved propeller. It could not be used on certified aircraft. Certification was so expensive that once a propeller or plane was certified it had to be produced for quite a number of years before the company would been able to recoup their invesment. Much of the knowledge relating to the carving of wood propellers existed only as "trade secrets" in the minds of certain men and when those men died some of it was buried with them.

I believe there are a lot of propellers being carved and sold for good prices, which are not well suited for the craft they are used on because they have been designed to the obsolete specifications and theories of sixty years ago. The propeller carver ought also to live closer to the plane on which his product is to be mounted so he can better tailor it for best performance. It seems to me that there are a lot of misconceptions about the working of propellers that are

TABLE of CONTENTS

Subject — Page

TABLE of CONTENTS (continued)

HOW I MAKE WOOD PROPELLERS.

Several months prior to the 1977 Fly-In at Oshkosh SPORT AVIATION carried an announcement asking for volunteers to work in the woodworking shop to demonstrate how one goes about carving a propeller. Thinking that I had had no formal training in that profession, and that there were quite a few much more eminent persons who were engaged in making propellers to sell, I planned not to offer my services. However at the next meeting of our local chapter various members very seriously urged that I should take part. I argued that I had had no training in this profession and no engineering degrees behind my name so who was I to presume to tell people how propellers should be designed and carved? In answer to that arguement they pointed out that I had designed and hacked out several propellers for my origonal design homebuilt and as far as they could see they certainly worked pretty good. I struggled with the idea for some time, trying to justify my abstention on the grounds that I was simply not qualified. Then one day the thought occurred to me that while it was true that I was not qualified to demonstrate how propellers should be carved, I was certainly qualified to demonstrate how I carved them. With that thought in mind I volunteered my services to Mr. Dave Yeoman.

At the 1977 Fly-In and again in 1978 most of the time I spent in the shop was used up in answering and reanswering the following questions,"What kind of wood is this?""How do you get the angles?" "Is pine strong enough?" "What kind of glue do you use?" "How do you clamp?" "Where do you get the airfoils?" "Why don't you use supercritical airfoils?" "How do you put the tipping on?" "Why do you use this blade shape?" "Why not a scimitar?" "Why are your tips so wide?""Do you use power tools?" "Why not?" "Aren't propellers hard to balance?" "How do you know what size and pitch to make them?" These questions and occasionally others were asked many,many times during those workshop sessions. I answered them as well as I could and once or twice made a few shavings to prove to them that I could at least use the tools.

In this book then, I will make an effort to answer all these questions again,, so that if you have forgotten what I said , or if you were not there in the first place, you can read my answers.

HOW I MAKE WOOD PROPELLERS.

Please bear in mind what I said a paragraph or so ago: namely, I am not trying to tell you how others do it, or how it should be done but simply how I do it and why. This is the one place where I can possibly claim to be an authority.

Before I make an attempt to answer these questions of yours I really ought to ask a few of my own. The first of these would be, "Why do you ask? Do you want to carve one for a plane of your own? Do you want to go into the business of propeller carving? Do you want to make propellers to mount clocks in? Do you want the knowledge for future reference?, or just out of idle curiosity?"

If you would want to carve apropeller for a plane of your own I would ask,"Did you build it yourself, or did you buy it?" If you bought it, and it had a regular aircraft engine, I would likely advise you to buy the propeller also. Fitting store bought aircraft engines with home carved propellers is not really a job for the beginning carver. Especially if the engine is in the"over 100 HP class." Not that it can't be done, but the company that made the engine probably wouldn't be too happy about it. Aircraft engines are engineered out closer to the "brink" than other engines are. Not that they are made stronger than other engines are, because they are not. They are designed to operate closer to their ultimate limits than automotive engines are in order to improve their power to weight ratio. Consequently the equipment to be used with them must be suited to their specific set of operating conditions. Besides for this particular engine and for a plane in your speed range there might already be a commercially produced propeller available that would fit it very nicely. It is true however that for many homebuilt aircraft there are no propellers from ATCed aircraft that are suitible. In this case the only solutions are custom made or home carved. A good home carved propeller that is well"tailored" to your particular aircraft and engine combination can easily give much better and safer performance than an ATCed one that is not. If you bought the plane already built even though it is an experimental design, you just might not have the discipline nor the ability to complete one on your own.

HOW I MAKE WOOD PROPELLERS.

The whittling of wood propellers is as much of an art as it is a science. It requires certain skills and the understanding of certain aeronautical priciples plus a few engineering rules.(really quite simple ones). This is so the carver knows what it is that he is trying to do. This knowledge is not gained by peeling a few more greenbacks off the roll. It requires the expenditure, in a rather coordinated way, of considerable mental energy. Nothing impossible, mind you---, but often quite a bit more than many care to put into it.

If you built the plane yourself,--all of it, not just assembled it from parts, and if it is of wood or has wood wings, and you did them, your chances of making a sucessful wood propeller could be quite good. If you designed the plane yourself and it uses a non-standard engine it is even more than likely that you could learn propeller designing and carving and it could be very much to your advantage to do so. If you just want to carve propellers to mount clocks in, I am very sorry,--I have had absolutely no experience with them. I know nothing of the rules governing their power requirements. I do not even know if they should turn clockwise or counterclockwise!

Therefore, if you need a prop for a Corvair, or an aluminum Olds or Buick, or a Model A Ford or for any of the VW variations or mutations, or for some odd engine on some ultralite,---stick around, maybe this book can help you. In it I will try to answer all of your questions, even though I may not do so in just the same order that you have asked them.

I wish, however, to make one thing clear at this point,----namely; that I am not recommending that you use <u>my</u> methods, or the methods of anyone else for that matter, when carving propellers for yourself,or for any other person. I am simply describing how I have done it and why,--and what the results have seemed to be. Should you choose to do things in the same way as I have described in this book, that is your decision. You must take the risk for it. And please remember,--a turning propeller is a very dangerous thing,--so keep yourself, your children, your friends, your dogs, and other loose objects out of its reach.----Good luck.

How do you know what pitch and diameter you should make them?

To tell the truth, you can't know,--.You have to guess! To be sure, there are many guessing aids. They are called formulae, or formulas. They may take the form of graphs, nomograms, or algebraic equations. They can start out with the assumed weight of a completely theoretical aircraft with X feet of wingspan and Y square feet of theoretical flat plate resistance, with such and such laminar flow airfoil, flying at such and such an altitude and temperature,and all that stuff, powered by a certain engine that develops Z HP at W RPM, or they can be quite elementary. They are useful for one thing only. They give you a set of figures for diameter and pitch that you can start guessing from. I never saw any two of them that gave the same answer. Nor am I sure that I have ever seen one that gave the specification the same as the prop used on any certain airplane. The more power you have to waste the more likely you are of having success when using them.

My suggestion for you is for you to find someone who has a plane exactly like yours, somewhat like yours, or remotely like yours and find out what he is using. Do this with as many as you can. I would not take his performance figures too literally, but I would not completely ignore them either. His airspeed could be off some. So can yours. I had one that was. His tachometer could be too. Some others have had that trouble.He just may though be quoting you performance figures that he would like to get , rather than the ones he is getting. The diameter and the blade width you can measure with a tape. Measuring the pitch is quite a bit more difficult, but it can be done with some degree of accuracy. If he tells you what the pitch is you still won't know for sure because you still might not know exactly what he means by the term "pitch". The pitch figures quoted by one manufacturer or amateur carver may not be directly comparable with those of another. One should find out from as many people as he can whose planes have engines like his, everything that he can, but he should not make up his mind yet because there are still more things to consider before making his guess.

HOW I MAKE WOOD PROPELLERS.

Popular Four Place, 150 HP 58" pitch prop 2000 ft altitude.

% power	% range	RPM	range miles	MPH Speed	SPEED Ft per min	Slipstream ft per min	% of Advance
50%		2110		104	9150	10200	88%
55%	100%	2170	850	107	9400	10500	88%
60%	94%	2230	800	111	9750	10800	89%
65%	89.5%	2300	760	115	10100	11100	90.5%
70%	85%	2360	720	118	10400	11400	91.5%
75%	80%	2430	685	124	10900	11700	92.5%
100%		2700		138	12100	13050	93%

Popular Two Place, 100 HP 50" pitch prop 2500 ft altitude

% power	% range	RPM	Range miles	MPH Speed	SPEED Ft per min	Slipstream Ft per min	% of Advance
40%	100%	2100	865	79	6950	8680	80%
46%	99%	2200	860	89	7850	9150	86%
53%	96%	2300	830	96	8450	9500	89%
60%	91.5%	2400	790	103	9100	10000	91%
68%	85.5%	2500	740	108	9400	10400	91%
77%	80.5%	2600	690	114	10000	10800	92%
87%	73%	2700	630	119	10480	11250	93%
92%	70%	2750	605	121	10650	11450	93%

These tables have been developed from data found in the Operations Manuals of these two aircraft. Note how the operating range decreases and the percentage of the advance per turn of the propeller increases as the percentage of the power being used is increased. These planes are equipped with metal propellers which are usually expected to give somewhat better efficiency than wood propellers can. It can be readily seen that a properly proportioned propeller will give an advance per turn ratio of about 7/8 to 9/10 when operating at 70% power. If it gives very much more than this it indicates that something is fishy somewhere. Either the airspeed is indicating to high, the tachometer is showing too low, or the propeller is too large in diameter and too low in pitch. If the advance ratio is much less than this, it could be an indication that the pitch is too large and the diameter is too small. If the latter case exists,(too small diameter, too much pitch), takeoff is rather adversely affected and if the oposite exists efficiency at cruise falls off considerably .

HOW I MAKE WOOD PROPELLERS.

During the years while I have been fooling with propellers I have come up with a number of "thumb" rules which, to me anyway, seem generally to be useful in the design of them, and also for the scaling up or down of a propeller intended for use on a different plane or engine. My dictionary defines " rule of thumb," as: 1. a rule based on experience rather than scientific knowledge. 2. any way of doing things that is practical though crude. I will attempt to explain them as I give them. Here goes:

1. The power required to turn a propeller varies in proportion to the cube of the RPM. Well,- this one should not be so difficult for the man who is a pilot. You note the tachometer reading at full throttle straight and level,(after the plane has accelerated up to maximum speed), then you retard the throttle until the tachometer reading is 9/10 of the maximum reading and you are at cruising RPM and airspeed at 73% power.(generally recommended). Take it back another 10% of the RPM,(to 80% RPM) and you will be operating at 50% power and quite close to "slow cruising" configuration. Take it back another 10% RPM (to 70% RPM) and you will be operating at 34% power in "slow flight" and very likely finding it difficult if not impossible to maintain altitude unless you are very lightly loaded, or your plane is very amply powered. Take it back another 10% (to 60% RPM) and you are definitely on your way down at 21% power. Going the other way, if you are going to do something to your engine,(remember now just to your engine, not to anything else), to make it turn up 10% more RPM static, you will have to increase it's power by 30%! Is this clear?

2. The power required to turn a propeller increases with the FIFTH power of the diameter. Or like this, power required is in proportion to $(\text{Dia})^5$. To explain it in more understandable terms, if we increase the diameter of the propeller by 10% we increases the power required to keep it turning at the same speed by 61%! Pretty drastic, isn't it? Or another example,-- it takes three times the power to turn a 5ft propeller as it does to turn a 4ft one! One more example; If we double the diameter of a propeller, we need 32 times the power to keep it turning at the same speed!

3. The power to turn a propeller also varies with the temperature, density, and the humidity of the air. (Density Altitude) These same

atmospheric conditions also influence the power output of the engine in very much the same manner, so their effects, while being very real, are not readily apparent in the readings of the tachometer. They appear more clearly on a hot humid day as you near the end of the runway and your plane is still not ready to leave the ground!

4. Thrust increases in proportion to the square of the RPM. (Increase the RPM by 10% and the thrust is increased by 20%)

5. Reducing the pitch by 2 inches (reducing the angle by about 1 degree), increases RPM by about 100 RPM.

6. Reducing the diameter by 1 inch (cutting ½ inch from each tip), usually increases the RPM by about 100 RPM.

7. Reducing the width of the blades by 1/6 usually increases the RPM by about 100 RPM.

8. Reducing the diameter by 1/8, (to 7/8) reduces the power required to turn it at the same speed by 50%.

9. The speed of an airplane increases in proportion to the CUBE ROOT OF THE POWER APPLIED!!!!! . This means in plain English, that if you **DOUBLE** the power, the top speed will be increased by **25 percent** . If you **TRIPLE** the power, the top speed will be increased by 40 percent

10. To find the pitch in feet needed, divide the speed in MPH by the RPM in hundreds, thus: $\frac{MPH \times 100}{RPM}$ = Pitch in feet. This formula allows for an average "slip" of 12% which is just about what it should be at cruise when both diameter and pitch are correct. At slow cruise it will be a little more, and at full throttle it will be a little less. This has been shown by a study of power settings, cruising speeds, RPM's, and cruising ranges made from the Pilot's Manuals of 2 popular certified aircraft. See page 4A.

11. A propeller with wide blades usually runs quieter than one with narrow blades and can give more ground clearance also.

12. High static thrust is not a reliable indicator of high propeller efficiency, although it will help you to taxi through mud and snow more easily. It is more important to have good thrust just as the plane is leaving the ground. We want the plane to quickly accellerate from lift off speed to climbing speed. This I think, is the most critical point in the whole flight. The reason that maximum static thrust is not so important is that airplanes are seldom operated

in that configuration. Only helicopters are operated there. A few aerobatic planes are operated there for brief periods of time.

13. According to the propeller formulas, propeller efficiency is governed most powerfully by pitch / diameter ratio. It will be considerably higher if the plane and engine combination allows it to fly fast enough to use a pitch/diameter ratio of 85% rather than if it must use a pitch /diameter ratio of 50% or less. The higher Reynolds number of the faster flying plane also contributes toward its better performance. Henri Mignet, designer of the Flying Flea said way back in 1930 that an angle of 15 degrees was needed at the tip of the propeller if one is to achieve good propeller efficiency.

14. It is possible to have too high a pitch /diameter ratio also for highest propeller efficiency.

15. The tip speed of a wood propeller should not exceed 850 feet per second. This is about 3600 RPM for a 51 inch prop.

16. A four blade propeller, if it is designed properly can often give as good performance and run more quietly than a two blader, plus giving a little more ground clearance.

17. It is not possible to accurately compare the performance of two propellers without a manifold pressure guage, a tachometer alone will not tell the whole story.

18. If the plane is rather underpowered, then the propeller must be optimised for best takeoff and climb, rather than for best cruise, because if you cannot takeoff, obviously you cannot cruise. This is probably the reason some oldtimers will tell you to use the biggest propeller possible, but I believe that on an adequately powered ship best performance usually comes with a smaller higher pitched prop.

19. To find the diameter of the propeller needed for some odd engine or plane where no experience is available, use the following formula found in the January 1970 SPORT AVIATION page 20 "Getting the Maximum Performance From Your Airlane" For a wood propeller it is:

$$\text{Diameter} = 285\sqrt[4]{\frac{P}{N^2\ V}}$$

This is where P is the maximum brake horsepower at sea level. V is the speed of the airplane in miles an hour at maximum power. N is RPM at maximum power. Now to some people this formula is going to look like a lot of Greek, but it really ain't all that bad. You guys who own those little electric calculators shouldn't have any trouble. So let's try it.

Suppose we say we have this VW engine that is supposed to have been all hopped up and the guy we got it from tells us that it is able to give us 65 HP at 3600 RPM. We think that this will give our ship a top speed of 120 MPH. Our aswer is supposed to be in feet.

Translating our formula into English it says: The 4 th root of 65 divided by the 4 th root of 3600 squared times the 4 th root of 120, ---then multiply this answer by 285. This last answer then will be the diameter in feet. Yah, Yah, but how do you take 4 th root?? Oh! That's easy you just take the square root twice!. Let's go!

MMMM let's see, the square root of 64 is 8 and the square root of 8 is 2.828. That takes care of that. The square root of 3600 squared is 3600, the square root of 3600 is 60. The square root of 121 is 11, and my slide rule says that the square root of 11 is 3.32. So now we have:

$$\frac{285 \times 2.828}{60 \times 3.32} = \frac{807}{198} = 4.07 \text{ Ft or } 49 \text{ inches}$$

72X40

O. K Our answer is about 4 ft 1 inch or 49 inches

Now let's look again at what Rule No. 10 said about pitch. What it really said was that pitch in feet= MPH X 100 divided by RPM. So-, 120 X 100 = 12000 divided by 3600 = 120/36 = 3.333 ft = 40". Now wasn't that easy? Our propeller is supposed to be 49X40, but <u>remember</u>----, I said that's just a place <u>to start guessing</u>!

But how do you go about guessing? Well I figure that the way to do is to guess so that if you are wrong that you can guess again. What do you mean by that? I mean guess on the big side first. Then if it is too big I can always cut it down,--- but if it is already too small, it is awful hard to cut something <u>onto</u> it. I think, at first I would guess that that hopped up VW ain't gonna be quite 65 HP 'cause I read somewhere, I won't say where, that some one said, that he tested a well advertised 2100 cc engine on the manufacturer's own dynamometer and after much fiddling and tweaking ,he was finally able to get 65HP out of it. so don't over estimate your engine. As it gets older it is more likely to lose power than it is to gain it. I would guess that a good single placer could quite easily make 120 MPH on 65 horses because I know of some which have done it on less. I would guess 50 inches diameter and 39 inches pitch and a bit wider blades than most people make. I would make sure that it will turn 2900 static before ever trying to take off with it. You've got to get rated RPM or you are not going to get rated HP and with the usuall fixed pitch propeller this does not occur until full speed in level flight is reached. Thus with the usuall wood propeller, unless the engine overspeeds at full throttle in level flight it is unlikely that more than 90% power will be available at the propeller hub at liftoff. If the propeller turns too slowly at static runup either the pitch or the diameter or both must be reduced, but care must be exercised so as not to overdo it.

Again I wish to remind you that propeller designing and carving is <u>not</u> an exact science, but a mixture of science and art, tempered by experience. Some of that experience can be the experience of some-one else. This is what we call education, and this is what this book is trying to do, but the individual must also must participate if he is to become proficient. The formulas that I gave you earlier were given to show you where to start guessing. Some of the other inform-ation is intended to show you how I have guessed and how those guesses have turned out. I hope that all these many words will contribute toward making all your guesses more successful.

Back on page 4 I speak of one of the ways I have used in hopes of making my guesses more successfully. It is called copying. A very profound idea isn't it. It is strange that in our society we should look at this rather simple act with such intense feelings of approval and disapproval at one and the same time. A little more meditation on the subject has lead me to the conclusion that copying itself is not bad but it draws its merit or dismerit from the thing that is being copied and from the purpose for which the copying is being done. So with this little example of mental gymnastics to justify my actions (we all do this all the time,--well,--almost all the time) when I have seen something that I thought was very good, I tried to copy it. Therefore I have copied quite a number of propeller designs which I had admired. To facilitate that copying or "adapting" I have compiled a set of tables to make the job easier for myself or for anyone else.

SQUARES CUBES and FIFTH POWERS of NUMBERS

Number	Square	Cube	5 th Power	Number
1	1	1	1	1
2	4	8	32	2
3	9	27	243	3
4	16	64	1,024	4
5	25	125	3,125	5
6	36	216	7,876	6
7	49	343	16,807	7
8	64	512	32,728	8
9	81	729	59,049	9
10	100	1000	100,000	10
11	121	1331	161,000	11
12	144	1728	248,832	12
13	169	2,197	371,000	13
14	196	2,744	538,000	14
15	225	3,755	845,000	15
16	256	4,096	1,037,000	16
17	289	4,913	1,416,000	17
18	324	5,832	1,832,000	18
19	361	6,959	2,514,000	19
20	400	8,000	3,200,000	20
21	441	9,261	4,084,000	21
22	484	10,648	5,153,000	22
23	539	12,397	6,677,000	23
24	576	13,864	7,886,000	24
25	625	15,625	9,765,000	25
26	672	17,580	11,814,000	26
27	729	19,650	14,176,000	27
28	784	21,900	17,289,000	28
29	841	24,400	20,520,000	29
30	900	27,000	24,300,000	30
31	961	29,700	28,300,000	31
32	1,020	31,800	33,800,000	32
33	1,084	36,000	39,000,000	33

SQUARES CUBES, and FIFTH POWERS of NUMBERS

Number	Square	Cube	5 th Power	Number
34	1,146	39,300	45,000,000	34
35	1,225	42,800	52,500,000	35
36	1,296	46,500	60,000,000	36
37	1,369	50,700	68,000,000	37
38	1,444	54,800	79,000,000	38
39	1,521	59,000	89,000,000	39
40	1,600	64,000	102,400,000	40
41	1,681	69,921	114,000,000	41
42	1,764	74,088	130,000,000	42
43	1,849	79,409	149,000,000	43
44	1,936	85,184	164,000,000	44
45	2,025	91,125	182,000,000	45
46	2,116	97,336	205,000,000	46
47	2,209	103,823	227,000,000	47
48	2,304	110,592	248,700,000	48
49	2,401	117,649	283,000,000	49
50	2,500	125,000	312,500,000	50
51	2,602	132,651	334,000,000	51
52	2,704	140,000	379,000,000	52
53	2,809	148,887	425,000,000	53
54	2,916	157,464	457,000,000	54
55	3,055	166,375	510,000,000	55
56	3,136	175,616	550,000,000	56
57	3,249	185,193	598,000,000	57
58	3,364	195,112	652,000,000	58
59	3,481	205,379	730,000,000	59
60	3,600	216,000	787,000,000	60
61	3,721	226,981	842,000,000	61
62	3,844	238,328	920,000,000	62
63	3,969	250,047	987,000,000	63

SQUARES, CUBES, and FIFTH POWERS of NUMBERS.

Number	Square	Cube	5 th Power	Number
64	4,096	262,144	1,072,000,000	64
65	4,200	274,625	1,160,000,000	65
66	4,356	287,496	1,248,000,000	66
67	4,489	300,763	1,348,000,000	67
68	4,584	312,712	1,440,000,000	68
69	4,761	328,509	1,564,000,000	69
70	4,900	343,000	1,681,000,000	70
71	5,041	357,911	1,804,000,000	71
72	5,184	373,248	1,935,000,000	72
73	5,329	389,017	2,074,000,000	73
74	5,476	405,224	2,218,000,000	74
75	5,525	414,375	2,379,000,000	75

With the tables of squares,cubes,and 5 th powers found on these last three pages it is posible to scale almost any propeller in diameter or pitch or RPM in different directions in almost any posible combination of ratios, to adapt the design to almost any engine or aircraft. Here's how it is done.

Let's say we have this 74x58 prop from a Cherokee 140. We like the looks of it very much and want to make a scaled down version of it to use on a 50 HP VW engine. The 150 HP Lycoming engine turned the big prop 2350 static. We want our VW to turn our scaled down copy 2900. This will require us to do some trial and error guess work like many engineering problems do. So let's guess that a diameter of 52 inches would be about right and see how it works out. We look in the tables of fifth powers and find the 5th power of 74 to be 2,218,000,000 and then we look again in the table and find the 5th power of 52 to be 379,000,000. Then we divide 379 by2,218 and get the answer .1708. We then multiply 150 HP by .1708 and find that it would take 25.6 HP to turn this 52X41 prop 2350, but we want it to turn 2900. Looking in the cube table we find the cube of 2350 to be 13,000 and the cube of 2900 to be 24,400 or 1.88 times as geat. We multiply 1.88 by 25.6 and find that it will take close to 48 HP to turn this 52X41 prop 2900. If 41" is not the pitch we want we can adjust that too by exchanging 2 inches of pitch for 1 inch of diameter. This will work in either direction, (either up or down) thusly, 53X39, 54X37, or 51X43, 50X45. Remember everything must be kept to scale. Remember also that in general wood propellers are a little shorter than the metal ones of the same HP rating because of the extra thickness needed in the blades of the wood one, but when that is taken into consideration this method works quite well.

What about speed reducers?

My answer will have to be that I have had exactly no experience with them. That does not, however keep me from having an opinion on the matter. I just haven't needed any on my plane. I am sure that contrary to what some people seem to think, there is no magic in them. Using a tiny fast turning engine and belting or gearing it to an extra large slow turning propeller does not insure spectacular success. It helps only if you <u>really</u> need such an arrangement. I am not talking about 1000 HP radials or military Vee's here. I am talking about VW's Corvairs, various motorcycle, snowmobile, chain saw, and lately some water cooled automotive engines. Installing a speed reducer between your engine and the propeller will add weight, complexity, and another place for mechanical breakdoun to occur. Some of us do not need more of these things, we have enough already.

There are a couple of things that a speed reducer can do that can be beneficial. It can prevent the propeller tip from going beyond the 850 FPM limit on speed, and it can make possible the use of a propeller with a more favorable pitch/diameter ratio. These are especially important on slow flying planes with fast turning engines such as most ultralites. There remains the question though whether it would not be more advantageous just to speed the plane up a little to get it into a higher wing loading where it could better cope with wind and weather, and where better propeller efficicency can be attained without gearing. I can't help but believe that the little French Cri-Cri's give more total performance and usefulness than most of those aluminum and cloth 30 MPH "Wonders" do.

Two more disadvantages of speed reducers are: they can make it very difficult to start the engine by propping. A friend of mine is building a KR-2 mounting a Corvair engine with a planetary speed reducer which gives a reduction of 16:10 and also reverses the rotation. He has not run it but, is beginning to fear that he will break the propeller trying to start it, it turns so hard. The engine on the prototype PL-4 was also said to be almost impossible to start by propping and its performance figures didn't show any particular advantages over comparable direct drive designs. Its designer boasted of its great amount of static thrust, so great that its brakes could not hold it at static runup, but when I saw it fly the takeoff run seemed to be as long or longer than for the average VW powered ship and its climb was nothing to become ecstatic about either. If a better propeller efficiency was realised through the use of the larger slower turning propeller with its better pitch diameter ratio, it all must have been used up by the extra weight of the longer landing gear, the larger propeller, and the speed reducer itself and the power dissipated in it, otherwise why wasn't the advantage visible? The other disadvantage of the speed reducer is, that just as it is possible to have too low a pitch/diameter ratio for best propeller efficiency, it is possible to have too <u>high</u> a pitch/diameter ratio for best efficiency. This can contribute toward propeller blade stall and poor static thrust. Therefore if one feels that he must use a speed reducer on his engine or he cannot be happy, he should use it in a situation where it can help him, not where it will only make the mechanism more complex.

I'm sorry but those seem to be my sentiments on that matter.

From time to time SPORT AVIATION has printed articles about propellers and propeller design and carving. Some of them have contained not only valuable information but also occasionally stuff that was purely theoretical in nature, which was expounded many years ago by some eminent professor, who because of his honored position, no one dared contradict.

Recently there have been some very good articles by George B. Collinge, called "<u>Lift and Thrust-,How Propellers Propell</u>". SPORT AVIATION, June 1981, pages 16,17,and 18, and August 1981, pages 19 to 25. This article is of a general nature but gives one many valuable insights. Occasionally it refutes sacred theories of yesteryear dealing with matters of diameter, blade width, number of blades etc., with examples from real life. The information requires careful and thoughtful study, but is useful as background material. There are two other articles which I consider as being very helpful, not because they are all encompassing, but because they give important pieces of information that other authors only allude to or do not mention a all.

The first is:
"Getting the Maximum Performance from Your Airplane".
By- L. G. Tucker
SPORT AVIATION Jan. 1970 Page 20.

It deals mostly with figuring propeller diameter and pitch from figures for engine power and top speed. It also shows how pitch/diameter ratio influences propeller efficiency, and how efficiency falls off very quickly if pitch is too small.

The second article is:
"Application of Wood and Metal Propellers".
By- Luther D. Sunderland
SPORT AVIATION Nov. 1973 Pages 15 thru 20.

This article deals mostly with propellers for the T-18. It also gives facts on airfoils and speaks to the distribution of pitch along the diameter of the blade of a specific propeller. No other article that I have ever seen has done this. Several other articles have only hinted at this matter.

This article also has a formula which enables one to calculate propeller diameter and pitch from engine power and RPM and aircraft maximum speed. Neither this formula, nor the one from the previously mentioned article can give one more than a clue to size and pitch. Like I have said earlier, it constitutes a place from which to start guessing.

I would advise that one should read and reread these articles from time to time. It takes time for all of the knowledge that is contained in them to sink into one's mind unless he is especially gifted. The part dealing with "camber" of airfoils on page 20 is also rather important and justifies thoughtful study. I believe that care taken in these points can make the difference between performance which is very good and that which is only so-so. It is the difference between a modern design and one that is archaic. (obsolete, outdated).

HOW I MAKE WOOD PROPELLERS.

Perhaps the best course to take at this point is to relate my own experiences during the years at propeller carving, especially those produced for my VW powered origonal design homebuilt "Die Fledermaus".

Propellers have interested me for almost as long as I can remember. Back about the time when Lindbergh flew accross the ocean my brother Harold and I read about someone who had built an airplane using for power a Model-T engine. Because Model-T's were plentiful at our farm,(much more plentiful than money), we decided we would put together something that could be taxied in the pasture in summer or over the snow on skis in winter, powered by a Model-T. I carved four propellers for it. The first, made from an oak 2X4 quickly disintegrated the first time we started it up. The second, made from a 4X6 was a little too big. The third was spoiled before it was finished, the fourth, made of hickory would spring too much while it was running because I had gotten the blades too thin. To remedy this we wrapped the blades with galvanized sheet iron and fastened it on with shingle nails! With this we were able to taxi just a little. During the 1930's four other dubious projects somewhat more seriously aimed at flight were begun. Most of these attempts were rather halfhearted because of lack of funds, know how, confidence, lack of time to really work at it, and from parental opposition. The last of these pre-war projects, the "Flying Flea" almost achieved its goal. It left the ground about a half a dozen times but did not leave the field. By this time I had carved 17 different props including 3 for wind driven generators.

When I joined the EAA in 1957 I made up my mind to build something using a VW engine, and produced a great many design studies and several false starts. John Thorp was just getting going with his T-18 at this time. because it looked like it had so many practical features, I borrowed some inspiration from it and from an all wood plane built in Canada called "The Westwind". The "keel" was laid for "Die Fledermaus" in the fall of 1964 but progress was very slow. My plans consisted of a side view at the scale of 1 inch= 1 foot drawn on a piece of brown wrapping paper, and a number of sketches made in some notebooks. Many mockups were also made, consequently it was

How I make wood propellers.

May 1975 before it left the field in the first test flight, powered by the 36 HP VW which I had converted myself and fitted with a propeller which I had designed and carved myself. Contrary to what some of my friends and acquaintences expected, it flew quite capably. After 15 tachometer hours of flight, circumstances led me to install a later model VW engine of greater displacement and it performs even better. Many of the people who, when I was building it, considered it with contempt, (seemed to anyway) and made jokes about it, now think it to be quite an accomplishment. I have made all of the propellers that have been flown on it, 21 so far, 17 two bladers, three 4 bladers, and 1 five blader. All of them worked pretty well, although some did work better than certain others. The plane has been taken off the ground and at least around the pattern 540 times to date, 8/7/84. Friends and neighbors have remarked about how effortlessly and quietly it seems to fly. It flies very nicely at about 50% power so that's where I cruise it. The people at the municipal airport where I learned to fly seem interested in it and often ask about it. It will leave the ground in noticeably less distance than the commercially built planes there do and get up to pattern altitude in much less distance too. I have 497 hours on it to date, (8/7/84) , 482 of them with the present engine. For the first 50 hours with the new engine I cruised it at 80 MPH indicated, then late in the fall of 1977 I built a sliding canopy for it. I noticed that with the canopy it would fly hands and feet off whereas it had always seemed to want to go off into a spiral before. The airspeed seemed to have picked up 3 to 5 MPH also. A few flights later I found that with only a little more RPM the speed would very easily come up to 90 and the scenery passed by at a considerably more satisfying rate. Several months latter I installed a manifold pressure guage and found that without the canopy or with it open, one inch more of manifold pressure was needed to keep us in the air. This in spite of the fact that the canopy increased the weight by 10 pounds. Another benefit is that one can fly quite confortably wearing the same clothes as he wears on the ground whereas before, one always had to add another layer or two in order to endure it. I realise that this little plane is not everything, but I still like it very much. I have loaded it with 35 lbs of camping gear and baggage and flown it to Oshkosh three times now, and people still stop and look at it.

How I make wood propellers.

How do you get the angles?

About twenty years ago, when I first made the conversion of my "36 horse VW engine, I tried various home carved wood propellers on it to get an idea of the amount of power it really could put out. Fifty-two inches, it seemed to me, (from the various formulae that I had to go by,) would be a suitable diameter, and if I wanted to cruise at 100 MPH, I would need, (I thought), 40 inches of pitch, so that is what I made. The engine was then started and run several times. At first it would go to 2500 but after about 30 seconds or so it would drop back to 2400. (It wasn't run in yet and was starting to tighten up). I had hoped to get something like 2800, Clearly this prop was two much for it.

The blades of this prop were 4½" wide at their middles and 2½" at the tip. I narrowed them ½" both at the middles and at the tips and tried it again. This time it went 100 RPM faster. I then made another with blades 3½" wide at the middle and 1½" wide at the tips and with what I felt was 32" pitch. This one turned 3100. The figure which I wanted was about half way between these two. The problem that really bothered me though was, "Where along this blade is that pitch actually measured? Is it the same all the way from the hub to the tip, or does it progress in some fashion from the hub to the tip?" The propellers on the planes I had looked at at the airports did not seem to have uniform pitch from the hub to the tip, nor did they have the same angle from the hub to the tip. But what <u>did</u> they have?

It so happened that at this time I had in my posession the propeller from a PT-19 in which my nephew had been a partner. Said propeller had been damaged while moving the ship out of the hangar, so it had to be replaced. As I pondered the above difficult questions, the thought occured to me that since I had in my hands this professionally designed propeller which had been produced for the military, where excellence was not secondary to cost as it often must be for the private market, I ought to study the design by making a drawing of it, and to the best of my ability measure such things as blade width, angles, thicknesses, and airfoil shapes, and to calculate the pitches at each of the seven stations with which I had divided the blade. Whew! What a long sentence! On the hub was stamped the following

How I make wood propellers.

following: Do not exceed 200 HP or 2400 RPM, the number 8661, and the name of the manufacturer.

When I began to measure the angles at the different stations I found that on this propeller the back side of the blade was not flat like many carvers make them, but was convex like the lower side of the wing of a modern airplane. To measure the angles one had to lay the propeller on the table with the back side down and measure from the table to the trailing edge, and from the table to the leading edge, and the width of the blade, this at each of the seven stations. From these measurements the angles at each of the seven stations were calculated. Thicknesses at each of the stations were measured and approximations of the airfoils were drawn, and the data recorded in a notebook. When the pitches at the various stations were calculated they were found to be as follows:

At the station 6"	from	the	center	25"	
12"	"	"	"	38"	
18"	"	"	"	46.5"	
24"				53.5"	
30"	"	"	"	60"	
36"	"	"	"	66"	
42"	"	"	"	72"	

10368000
172800
63360

So you see, this propeller certainly did not have uniform pitch at all stations. The diagram on page 16 B shows this data in a way that probably conveys these relationships best. With a graph like this and the Table of Squares, Cubes, and Fifth Powers shown on pages 9A, 9B, and 9C, this design, or any other design for that matter can be scaled up or down in diameter, pitch , RPM, or blade width to suit any engine or plane one might encounter, and still be similar to the origonal design. The answers would of course, like the answers from all the other forulae, be only approximate, very helpfull, a place from which to start guessing. From this diagram (page 16B) we could also construct a very reasonable facsimile of the prop on that PT-19 too. All that we don't have is the actual shape of the airfoils, but we could construct some quite suitable ones very easily.

How I make wood propellers.

On page 16 B (OppOsite) is that diagram mentioned in the last few lines of the preceding page. The heavy line along the left side of the page represents the center of the propeller. The very light line at the extreme right edge of the paper represents the extreme tip of the blade. The distance between the two is divided into seven one inch spaces each representing six inches along the blade of the origonal propeller. The narrow space after the last 1 inch space on the right is the space between station No. 7 and the tip.

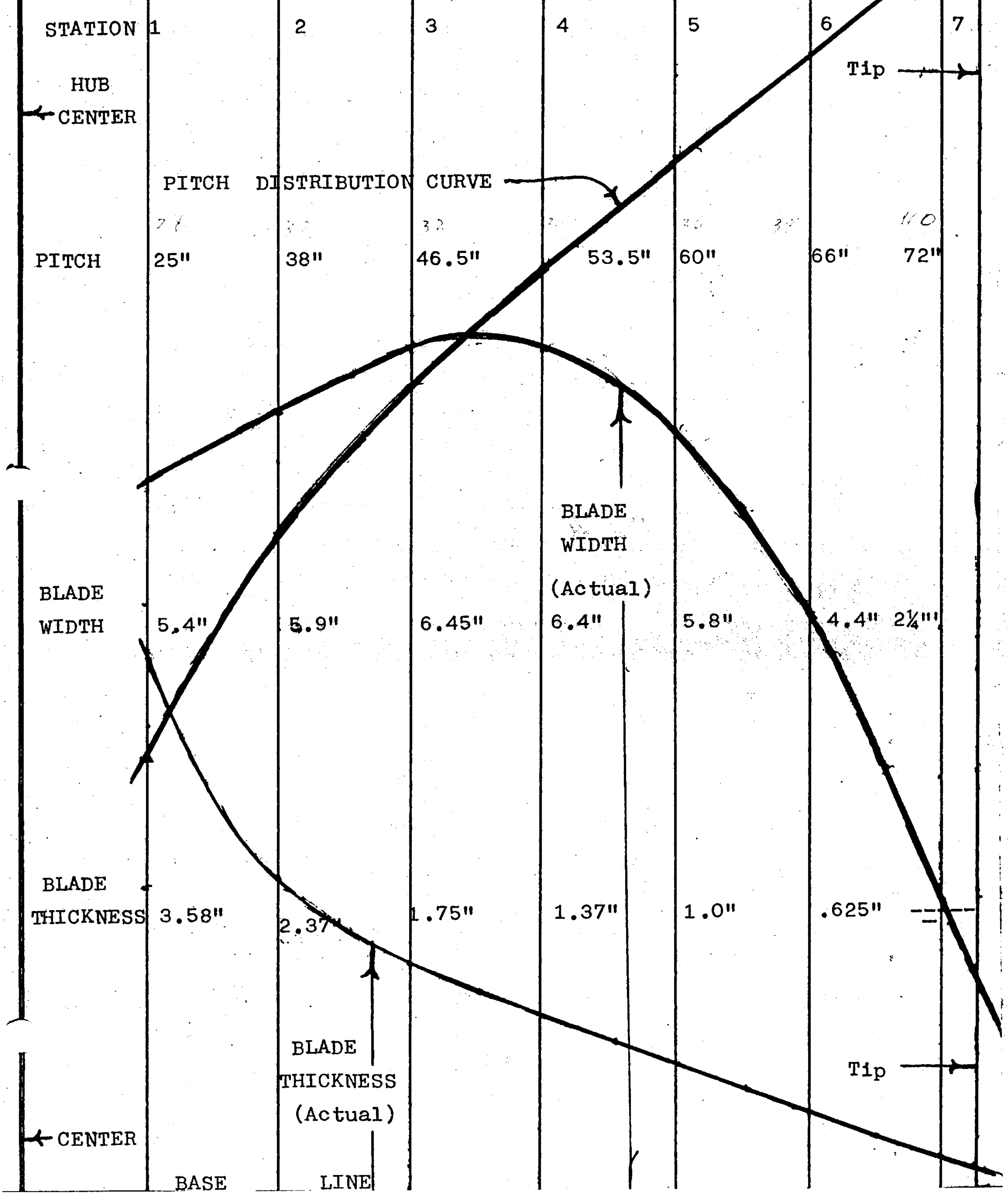
The heavy line accross the bottom of the page marked "Base Line", is the place from which the distances representing blade widths, blade thicknesses and pitch are measured. The distances between this "Base Line" and the two lower curved lines represent the blade widths and thicknesses at each of the stations. The scale here is full size. The upper slightly curved line represents the pitch of the propeller. For this line the scale is the same as it is for the diameter. One inch the graph between this line and the "Base Line" equals 7.57 inches of pitch. This "pitch line" on this graph is intended to provide a visual concept of how the pitch of this propeller, (remember not the angle but the pitch!) increases between the hub and the tip of the blade.

You say,"What is the difference between the angle of a propeller and the pitch of the propeller"? The answer is this.-- The angle of a propeller is the angle between the blade and the plane of rotation. The pitch of a propeller is the distance it would move ahead during one turn if it could be operating in a solid instead of in air.

So you see that a propeller does not pull the same amount of air at all points along the blade from the hub to the tip. Not this one anyway! Kinda shakes one up a bit, doesn't it? It did me anyway! But why should it be made this way? Wellll---l, I figger it this way,---. Back there before this prop was made, some engineer found out that the air didn't come through the center of the prop as fast as it did through the tips because there was no place for it to go--,-there was this big blunt engine coming along back there, and a big fat fuselage right behind that too, so why dissipate all that good power trying to make that poor air do what it could not?

DIAGRAM OF WOOD PROPELLER FOR PT-19 Showing;

Blade Width, Blade Thickness, Pitch and Pitch Distribution



How I make wood propellers.

One notices when he is driving his car while it is snowing lightly that some of the snow flakes are starting to get out of the way before the car reaches them , and after it has passed, it pulls a lot of them along with it, showing that it is taking a lot of air along with it as it goes. An airplane in a power off glide does the same, and one with an engine running full power is trying to too. Because of this "blockage"of the slipstream in front of the engine and around the fuselage, a propeller with too great an angle in this portion of the blade could experience "blade stall" over this portion of its diameter, especially at takeoff and during steep climbs. It could also give reduced performance during cruising flight. Some propeller designers still do not seem to recognize this, for one still sees "How To-" books on propeller making that show plans that would make the pitch uniform from the hub to the tip.

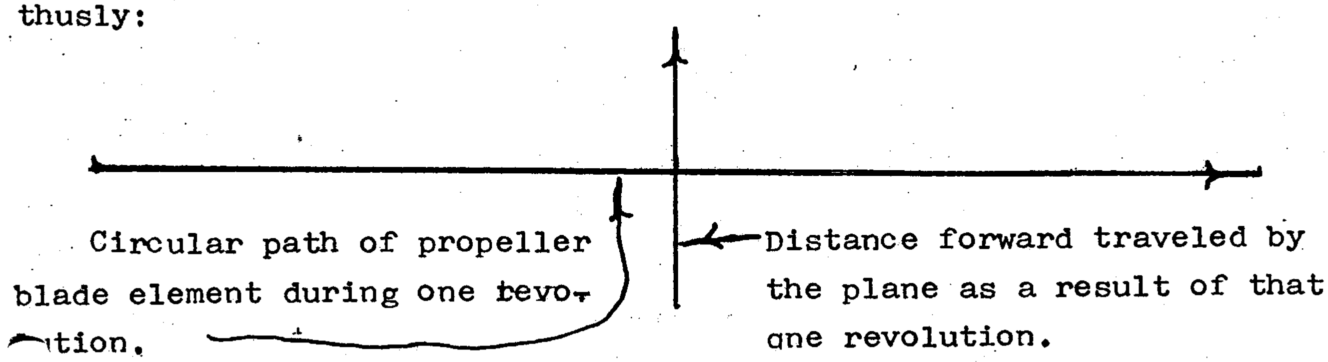
"Lu" Sunderland on page 19 of his article in SPORT AVIATION, Nov. 1973 talks about this same matter as related to the propeller on the Piper Cherokee and gives specific figures. Carefull reading and rereading of this part of this article should help one to comprehend what I am talking about here. I know that this matter, especially the amount of variation between the pitch at the hub and the pitch at the tip, was hard for me to accept, but 497 hours of flying while testing 21 different propellers has convinced me that that old PT-19 propeller wasn't so far off after all.

Some time after I had made this study of this PT-19 proeller I I made a scaled down, revved up version of it to try on my 36 HP VW. I used the principles found on pages 5, 6, and 7 plus the experiences I told you abput on the top half page 15 and came up with the diameter of 52 inches and the pitch 32 inches at about the 85% diameter point, and about 38 inches at the tip. When tried in June 1963 it turned 2800 static on 80 octaine aviation gas. Some time later I cut 1/2 inch from each tip and it turned 2900. In the fall of 1973 while I was running extensive taxi tests I tried it and it seemed to work very well, but I never used it for flight because of the excessive vibration it had after I added a one inch spacer block to the back of the hub. Nevertheless, I believe that it would have worked quite well.

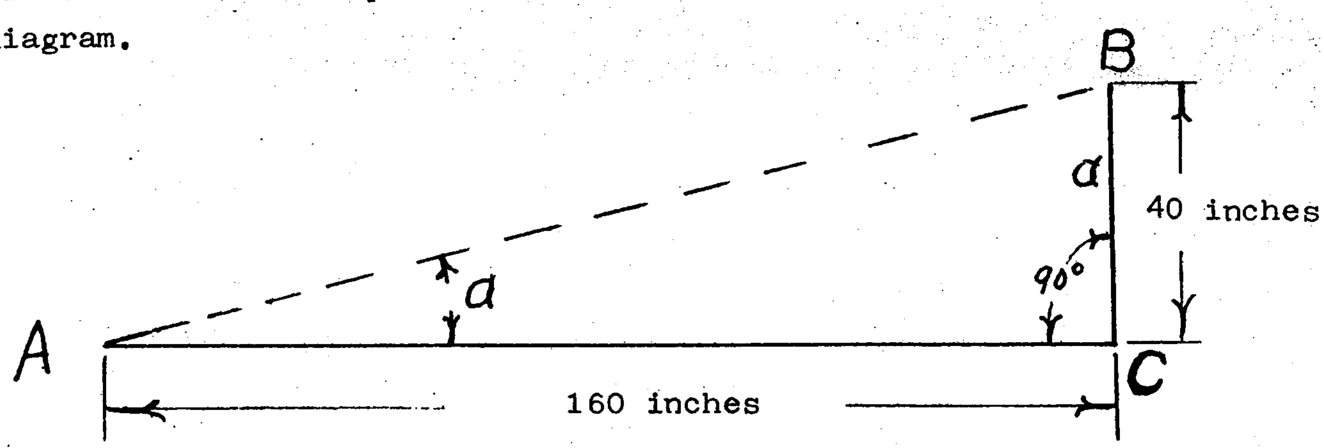
How I make wood propellers

An explanation of the term "Tangent" as used on page 17 and the following pages of this book.

In calculating the angles for the various stations along the blade of a propeller it is helpful for the beginner to draw diagram (to scale) showing the relationship between the pitch desired at that station and the circumference of the circle described by the blade at that station. A bit of thought applied at this point will reveal that these two motions or forces are working at a right angle to each other, thusly:



Assuming that we desire to build a propeller having a circumfer- of 160 inches and a pitch of 40 inches we draw the following triangular diagram.



Looking at the above diagram we have line AB representing the actual path traversed by the tipstation of this propeller during one revolution while the plane is in flight at cruise. Line BC represents e PITCH of the propeller, the distance the propeller is <u>trying</u> to move ahead during each revolution of the propeller. Line AC represents the circumference of the circle described by the tip station during one revolution at zero airspeed. Now if we divide Line BC (40") by Line AC (160") we obtain a decimal quanity which in Trigonometry is known as the TANGENT of the ANGLE. (angle α). This quanity will be less than 1.0 if angle α is less than 45 degrees, and greater than 1.0 if angle α is greater than 45 degrees. In this specific case we have 40 divided by 160 which is .25 . Using Scales D and T on our Slide Rule we find that this angle is a tiny bit more than 14 degrees. By using a Table of Natural Trigonomic Functions we could find the exact angle even more accurately. I believe that it is easier and a greater degree of precision can be attained by using these Tangents just as they are instead of converting them into degrees. All we need to draw them is a ruler. This is why my propeller specifications do not list the angles in terms of degrees ,but in terms of Tangents. The Tangent really expresses the relationship between the circumference of the propeller at the station under consideration and the amount of pitch existing or desired at that station. Verstehen Sie das?

Two other usefull relationships found in the Table of Natural Trigonometric Functions are: 1. Sine , which equals Line BC divided by Line AB (the hypotenuse). Thus by looking the Sine for the Tangent .25 up in the Table of Natural Trigonometric Functions, we will find in column marked " Sin" the decimal 0.2426. If we divide the length of Line AB, in our case 40 inches , by this 0.2426 we will obtain for an answer 164.9 inches, or 13.74 feet , the distance this particular blade section travels through the air while turning one revolution and advancing 40 inces. By multiplying this 13.74 ft. times the revolutions per second we obtain the speed in feet per second or section is traveling.

If we should so desire we could divide the length of Line AC, in our case 160 inches, by the decimal 0.9702 found in the column marked "Cos" and obtain the length of Line AB . In this case we would be using the circumference traversed by the section and the Cosine of the angle. Siehst du?

If you do not understand these last two paragraphs don't fret too much about it. One can make very good propellers without them. I learned most of what I know about Trigonometry when I was in my third year of highschool. I was already trying to design and carve propellers so I paid special attention in class. This was in 1933, 51 years ago.

How I make wood propellers.

But you still haven't told us how you get the angles!

O.K., O.K.,- Hold your horses! I'll get to that yet! First I must tell you how I determine what the pitches should be at the different places along the blades before I can tell you how I find what the angles should be.

Let's turn back again to pages 16A and 16B. Looking at 16B, we see the upper curved line representing the pitch distribution. As it crosses the station lines there are figures denoting the pitch at each station. The stations are six inches apart so the diameter at the first station is 12 inches, at the second station it is 24 inches, at the third it is 36 inches, at the 4th 48 inches, at the 5th 60 inches, at the 6th 72 inches, and at the 7th station 84 inches. Now I multiply the diameters at each of these stations by 3.1416 to find the circumferences at each of these stations. Then I make a table out of all these numbers like this:

:ATION	1	2	3	4	5	6	7
DIAMETER	12	24	36	48	60	72	84
CIRCUMF.	37.7	75.4	113.1	150,8	188.5	226.2	263.9
PITCH	25	38	46.5	53.5	60	66	72

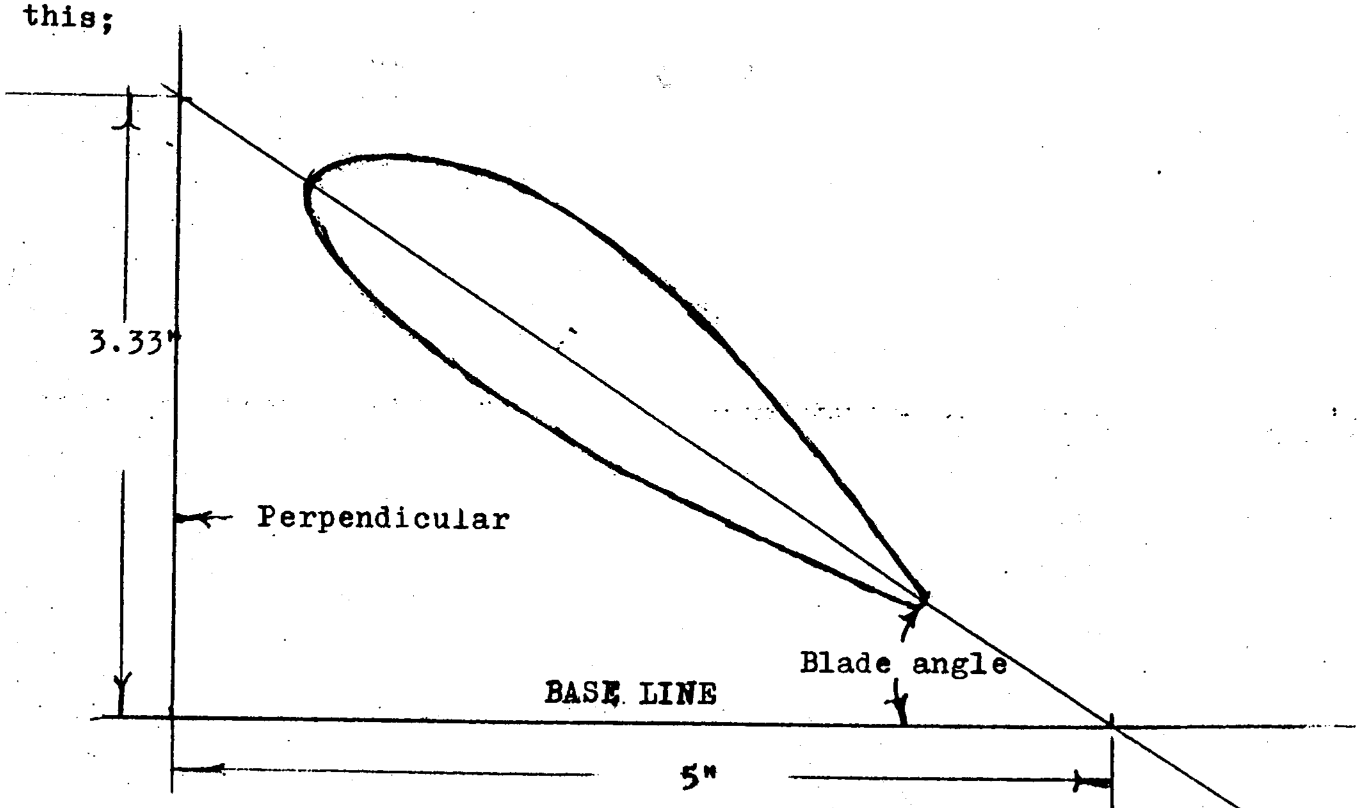
Now we divide the pitch by the circumference and we get a figure we call the tangent of the angle,(at that station), so:

TANGENT=	.666	.504	.413	.357	.313	.296	.273

We could look all these tangents up in a Table of the Natural Trigonometric Functions and find out what all of these angles are in terms of degrees, mimutes, and seconds, but we can work more easily and accurately if we use them just as they are. We won't need a protractor either, just a ruler to draw the angles. All we need to do is to draw a horizontal line 5 inches long. Then we multiply the tangent at the first station, .666 by 5, (the length of this line) and obtain the product 3.33. We then erect a perpendicular 3.33" high at the end of that 5inch line and then draw the hypotenuse between the ends of the 5 inch line and of the 3.33 inch perpendicular. The angle formed at the intersection of the hypotenuse and the 5 inch line is our blade angle at station number 1.

How I make propellers.

For the angle for station number 2 multiply .504 by 5 which equals 2.52 . Measure up 2.52 inches up on that same perpendicular and draw the line from that point to the end of the 5 inch line again and there you have the blade angle for station number 2. Continue this process until you have all of the angles for all stations drawn. If for greater accuracy you would like to draw them to a larger scale this can be done too. If you want to draw them double this size make your base line 10 inches long, multiply the tangent by 10 instead of 5 and measure up the perpendicular 6.66 inches instead of 3.33 like you did the first time for station number 1. This will give you twice as big a triangle as you had the first time and just a little bit more accuracy but take a bigger sheet of paper. The angle will be the same.
I usually draw a separate base line for each station and then draw the airfoil for that station right on that line full size like this;



This should be Simple enough for any one to understand. Make one of these drawings for each of the stations on the blade. On the next pages I will show you how I draw the Airfoils.

How l make propellers.

Where do you get the airfoils?

My answer is I draw them myself.

Yeah, sure! but <u>how ??</u>

It's not hard to do, but it does work better if you know what it is that you are trying to do before you start. You need to know what it is that makes an airfoil work.

There are three different terms we use when we are describing the main physical characteristics which affect the performance of an airfoil. They are: chord, thickness, and camber.

1. <u>Chord</u>. This word means the length of a staight line drawn between the extreme leading edge and the extreme trailing edge of the airfoil. This line may or may not lie completely within the physical outlines of the airfoil.

2. <u>Thickness</u>. This term may mean the maximum distance perpendicular to the chord line between the upper and the lower surfaces of the airfoil, or the distance between the upper and the lower surfaces at any specified point along the chord line. It may be expressed in terms of percentages of the chord of the airfoil, or in definite units such as inches,centimeters etc. The thickness of an airfoil affects the stall characteristics of a wing and the amount of space available inside it,into which one may put the necessary structure, fuel tanks, etc. In the case of an airplane propeller, the strength and stiffnes of the blade. (very obvious, isn't it?)

3. <u>Camber.</u> The camber of an airfoil meams the amount of the curve in the line which is equidistant from the upper and the lower surfaces of the airfoil. If the airfoil is symetrical, that is, the upper and the lower surfaces are exactly alike, this camber line will be straight and the airfoil will be said to have <u>no</u> camber. It will still lift, but not unless it has an angle of attack greater than zero. If it has a thickness of about 12 or 15 percent, it will give a maximum lift cofficient almost as high as a cambered airfoil, but will almost always have a sharp stall. It will also have a constant center of pressure(be stable). It will work as well inverted as it will right side up,consequently it is most often used for control surfaces and for wings on aerobatic aircraft. It does not perform as well on low powered or on heavily loaded aircraft as a moderately cambered airfoil. On a conventional airfoil(non laminar)

the amount of bend(camber) in this median line governs the optimum lift cofficient,(the value of the lift cofficient where the wing works best), usually chosen so that it occurs very close to the cruising speed. This optimum lift cofficient can be "guestimated" quite closely by multiplying the percentage of the camber existing at the midpoint of the chord by 4 times Pi (12.56). Sounds kinda simple,(too simple) but it really works. If that term "percentage of camber" leaves you dazed, it means the amount of bend in this median (camber)line expressed in terms of percentage of the chord of the wing. Experience has shown that 5% camber is about the highest practical camber for conventional aircraft. More generally used values are from 2 to 4 percent. The position of the point of maximum camber in terms of the distance from the leading edge is also quite important. As the point of maximum camber is moved either forward or aft of the center, greater lift is produced. The airfoil becomes more stable as this point is moved toward the leading edge. The camber of an airfoil may be positive (above the chord line) on the front part of the airfoil and negative,(below or right on the chord line) a short distance ahead of the trailing edge. Such an airfoil is said to be"reflexed". This technique is used to stabilize the center of pressure of the airfoil. It is not at all new but recently has been used to develop a whole slue of new airfoils for helicopter blades, some of which have since been appropriated to other uses. Former uses were for tailess aircraft, especially those of the "Plank" variety. "Laminar flow" airfoils usually have both their points of maximum thickness and of maximum camber more toward the trailing edge than conventional airfoils. The advantages of their special shapes can be completely negated if they are not constucted and maintained so that their surfaces remain very clean and smooth(not wavy). When they are not that way they can give much worse performance than old time conventional ones. Besides having all the effects on the performance of an airfoil that I have so far mentioned, camber,especially the amount of camber at the midpoint determines the angle of attack at which the airfoil ceases to develop lift. This angle is very easily found. No need to consult any fancy reports or pretty graphs for this. Just draw a line through the trailing edge and the midpoint between the upper and lower surfaces at the mid point of the chord and that is the "ANGLE

OF ZERO LIFT",period! --- If it is on a propeller it is the Angle of ZERO THRUST at that particular point on the blade!

Probably the next most important factor which can scuttle the bright hopes of an aircraft designer choosing the correct airfoil for his ship or his prop is the one called "Reynolds Number". It really ought to be called "Reynard's Number"! This "foxy" rascal has probably fooled more amachoor aircraft designers when they were trying to decide which exquisitely exotically magical airfoil they should choose for their superspecial awardwinning home designed aircraft, than any other single factor.

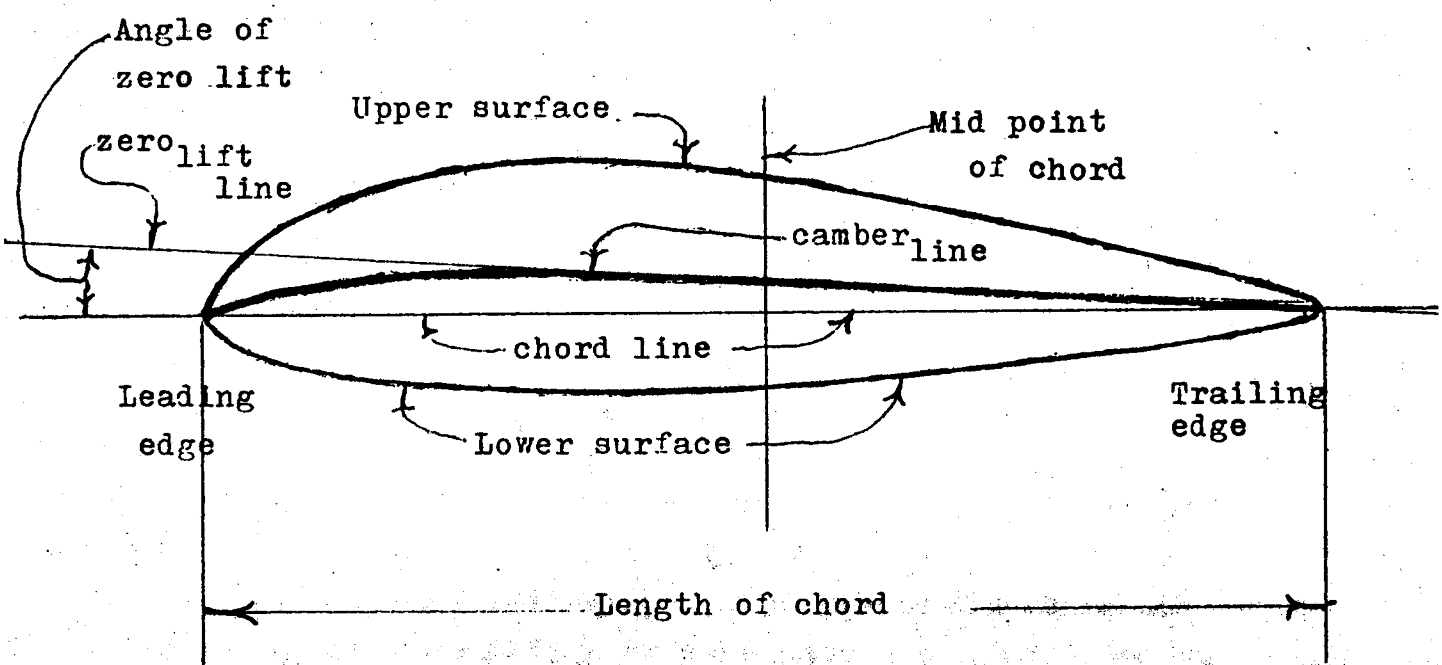
"Reynolds number" is a term engineers use to denote the cumulative effects velocity, size, and density of the air (density altitude) exert upon the lift and drag of an airplane. Another less sophisticated but more descriptive term is "scale effect". What really happens is that as an aircraft is designed to fly slower, be smaller, or is operated at a higher density altitude,performance is eroded,(in just plain English,performance turns out to be poorer than one would ordinarily have expected). This seems to apply especially when using when using many of the modern laminar flow airfoils. These airfoils were designed for jet fighters, airliners and executive ships,and when used on VW powered planes cruising at 100 and landing at 50 MPH ,all their promised advantages, if they had any in the first place, are found to have evaporated. These airfoils shine, if they shine at all,at a Re no. of 9 and 12 million , but a plane like Die Fledermaus cruises at 3,000,000 and lands at 1,600,000 and at that figure performance for most of the US laminar airfoils is so poor they are not even listed. Airfoils developed in Deutschland for sailplanes seem to be better in this respect.

It is useless to spend a lot of time trying to select the very best airfoil for an aircraft because many other factors influence the performance of the finished product to a much greater extent than selecting the very best possible airfoil. In spite of the thousands of airfoils that have been tested down through the years, only about a dozen or so are in use on general aviation aircraft today.

"But-," you say, "Why such a long sermon on airfoils??" We are not building wings. We are trying to carve a propeller!"

To this I reply; A propeller is a little wing which has chord,camber, thickness, velocity, wing loading, angles of attack, and optimum values for all of these factors, just as a wing does. While none of these are extremely critical, it is important that all should add up toward the most favorable solution, rather than toward an unfavorable one. In other words we want to make all of our compromises in the right places.

The drawing below illustrates some of the points made in the text found on the last few pages.



The distance between the camber line and the chord line when expressed in terms of the length of chord is called the percentage of camber. The angle of zero lift shows how much negative attack the airfoil must be given to make it stop lifting.

The airfoil in the above drawing was used on a propeller carved for use on a Corvair powered Aircamper. This section was located 1/3 of the distance from the center to the tip. Actual size and shape.

Various experienced propeller carvers have stated that to have a certain airfoil section on the propeller is not all that necessary, but it is most necessary that oposite blades be as alike in every way as they possibly can, and be thick enough so they do not flutter. Camber of the blades should be similar in value to that of the wing of the plane on which it is mounted. The angles derived from the calculations of pitch should lie along the chord line of the airfoil, not along the lower surface of it. Trailing edges should be rounded to a radius of about 1/16 of an inch. This is so that they do not become too fragile and split off, and so that they do not cut your hand when you crank the engine. There is no great gain in making the blades extra thin, but they should not be too club like either, unless the prop is intended for use on an airboat. Airboat propellers are subjected to much more abuse than aircraft propellers are, namely: from brush along the shore overhanging the water, and from the blocking action of the motor and the motormount structure in the airstream ahead of the propeller. This is the cause of much of the noise generated by airboat propellers. Airboat propellers sometimes dip in the water or strike chunks of ice in the water when the craft goes off the ice into the water, or climbs out of the water onto the ice.

Pages 67B,-C-D-E-F-G and 68 . Show a plan for a propeller I made some years ago for a Corvair powered Aircamper. They give a good idea how the airfoils and other things should look and also tell how the propeller turned out and what I did about it.

I make my airfoils like the ones shown in this drawing and make templates for each of the 6 stations from the hub to the tip. This is done to get the angles right and both blades exactly the same. Many carvers make the whole back side of the blade, or almost the whole back side of the blade flat, and do not use templates for any of the airfoils. They just use a contour guage to get the curved front sides of the blades like each other. They use a large protractor and a sliding T bevel (a kind of adjustable trysquare) to get the angles right. They say that it is easier and quicker to do it their way but I do not think it is better. I usually design my propeller blades a little thicker than I think they need to be, and then sometimes thin them a bit after I have flown the prop a few times. The tips of the blades can be covered with fiberglass if they seem too thin or if I am afraid of them splitting.

To some, this constructing of templates for carving the airfoils may seem like a tedious job, but when I have them done I can carve a whole family of propellers with this one set of templates. If I want another propeller with just a little more pitch I make the blade just a little longer, say 1½ inches longer and set the stations proportionately farther apart, then when I am finished carving it I have a propeller that is three inches larger in diameter and with a trifle over two inches more pitch. When I try it on the engine it should turn 400 RPM slower than the other one did. Then if I should cut one and one half inches from each tip it should turn about 100RPM slower than the first one did, and I would have a propeller that was the same length as the first one, but with two inches more pitch. If I should cut ½" once more from each tip I would have a propeller that is one inch shorter than the origonal but with two inches more pitch. It should turn approximately the same speed as the origonal. The tip of the blade though, would be just a little wider and a little bit thicker than the origonal. It could be thinned some if I should wish. This process can be used the other way too, to reduce the pitch of the origonal propeller, to reduce both the pitch and the diameter of the origonal, or to build a new one with a reduced pitch and a larger diameter.

I can also use these same templates to build a considerably larger or smaller propeller for a different plane and engine if the pitch/diameter ratio is right for the combination of plane and engine you are to put it on. This requires careful thought though if you are to achieve success.

Why do you use this shape? Why not a scimitar shape?

I use this blade shape because I want the blades to be stiff and not to flex too much in flight. Back in the "old days" (50 years ago and before) there were many differeent shapes. Some of them looked like they were the result of much theoretical supposing and were intended to balance the forces of thrust and torque against the centrifugal force of the rotating blades, and to use thrust forces to twist the tips to a lower pitch in an effort to dampen the tendency for blades to flutter. Aircraft engines turned slowly those days. Many of the WW-1 engines ran at 1300 RPM and some even slower. Propellers and cylenders were large. Perhaps these forces could be balanced for one speed but it is doubtful if even this was accomplished. Pictures of German WW-1 props show much straighter blades. We were told by a famous race pilot and also by a famous propeller carver, I don't recall whether at Oshkosh or at Rockford, that these fancy scimitar shapes try to straighten out at high RPM and tend to crack. Besides this they just do not accomplish

How I make wood propellers.

what is expected of them. They do not really give any special advanages. The writer of one of the articles recommended in this book, stated that a famous propeller makes designer said that their propellers were designed not to spring but to be as stiff as possible, and that they could see no reason for making blades anything but straight.

During the years between 1930 and 1960, we saw advertised many automatic propellers based on springing blades, blades which balanced centrifugal force against thrust, and props that balanced thrust against springs, in order to accomplish pitch changes automatically. I see these very seldom today. Why?

There is a force generated by propellers which many pilots seem to have forgotten exists. It is the force of gyroscopic pecession. It can be very powerfull. If you want to get a faint idea how strong it can be , Take about a 1/2 horse electric motor with a rather large diameter pulley on it, and while it is running pick it up and swing it around as if it were a model airplane doing aerobatics. Maybe then you can have a faint idea of what the forces of precession are trying to do to your propeller flange and crankshaft in really rough weather. At a Fly-In at OSHKOSH I saw a four blade propeller being installed on a Scale P-51, and it took four men to lift it up there. Think of the precession it would have!

The propeller on my"Fledermaus" weighs only 3 pounds. I like it that way. I think the lighter ones run smoother than the heavy ones. Propeller blades do spring in flight. I have seen them do it. On my " Fledermaus", under certain conditions I see the propeller as a faint disk and when flying one of my rather thin bladed 4 bladers I could see the disk flex with the turbulence. I try to make the blades on my propellers rather stiff, and to do this I shape them so that where the blade meets the hub is the widest or almost the widest part of the blade.

Why are the tips of the blades so wide?

"Die Fledermaus" was designed to meet a number of conditions, including resistance to groundlooping, noise abatement, and good takeoff and climb performance with a VW motor. The wide blades do several things. They allow the use of a smaller diameter propeller, which allows the prop to turn faster before exceeding the 850 FPSec. limit for the tip speed for wood propellers. Propellers with wide blades run quieter. A smaller prop lets the plane set closer to the ground so that the pilot can see over the nose when in three point attitude and can see where he is taxiing. It also keeps the center of gravity lower and thereby reduces the tendency toward groundlooping. Propellers with wide blades are said to be less subject to blade stall and to work better in a climb. I have quite a few people remark to me how quietly and effortlessly my plane seems to fly. I have flown behind one 4 blader 45 inches in diameter, two 4 bladers 46 inches in diameter, and one 5 blader 46 inches in diameter, so I know that a propeller for a VW does not have to be 54 inches in diameter. I do think though, that with these small props this matter of the distribution of the pitch along the blade becomes more important. In one of those articles in SPORT AVIATION the statement is made that adding blades to the propeller to increase the blade area is less detrimental to performance than adding width to the existing blades, but how much less he does not say. Some day I intend to find out how short and wide a two blade prop can be and still give satisfactory performance.

This matter of Reynolds Number must also come into influence here too. On my plane the Reynolds No. of the wing is about 2,700,000 at 90 MPH. My best 2 blade propeller, the Butter Paddle Special, has blades 4 inches wide at the tip. The diameter is 50 inches and it cruises 90 MPH at 2900 RPM. The pitch at the tip is 39.3 inches thus the tip goes the helical distance of 13.45 ft per turn and is turning 48.3 turns per second. 48.3 X13.45 = 650 ft per sec tip speed. At 90 MPH the plane is traveling 7900 ft per min or 131 ft per sec, 1/5 as fast as the tip is going. To get the very best efficiency it should be going 1/4 as fast as the tip of the propeller. To do this it would have to go 25% faster. It would take double the power to do this. Getting back to that Reynolds No. again, The tip of the blade is going 5 times as fast as the plane, but the chord of the tip is only 1/10 as great as the chord of the wing-, so 1/10 X 5 = 1/2 , or the Reynolds No. of the tip of the prop is only 1/2 x 2,700,000 or 1,350,000 which is getting pretty darned low. If the tips were only 2 inches wide Re. would only be 675,000 which would seem to me to be way down the line. At least it would be very low. as aircraft wings are concerned. With a 45 inch 4 blader the tip be going 12.16 ft per turn X 48.3 turns per sec= 588 ft per sec tip speed, or 400 MPH. Getting pretty close tothe ideal of 3.92/1 for tip speed to aircraft speed. Within the realm of possibility.

How I make propellers.

What kind of wood do you use?

Propellers can be made from many different woods. I have made them from oak, hickory, ponderosa pine, white pine, fir, mahogany, and now I am helping make one of yellow pine. Many commercially built propellers are made of birch. Different woods have different carving characteristics so different techniques may have to be used. Some other wood which may be easier to carve may require the blades to be made thicker because that wood may not be as strong as some others. It is important that it be dry and free from knots and other flaws and straight grained. It must also have good gluing characteristics. It does not need to be quarter sawed. For a propeller of the size for a VW 3 or 4 laminations are enough. Sometimes one sees a propeller with very thin laminations. This is done to make them less susceptible to the entrance of moisture and the warping and inbalance therefrom, the many joints made with waterproof glue act as vapor barriers. The thinner laminations cause the material in the resulting blank to be more homogenious also.

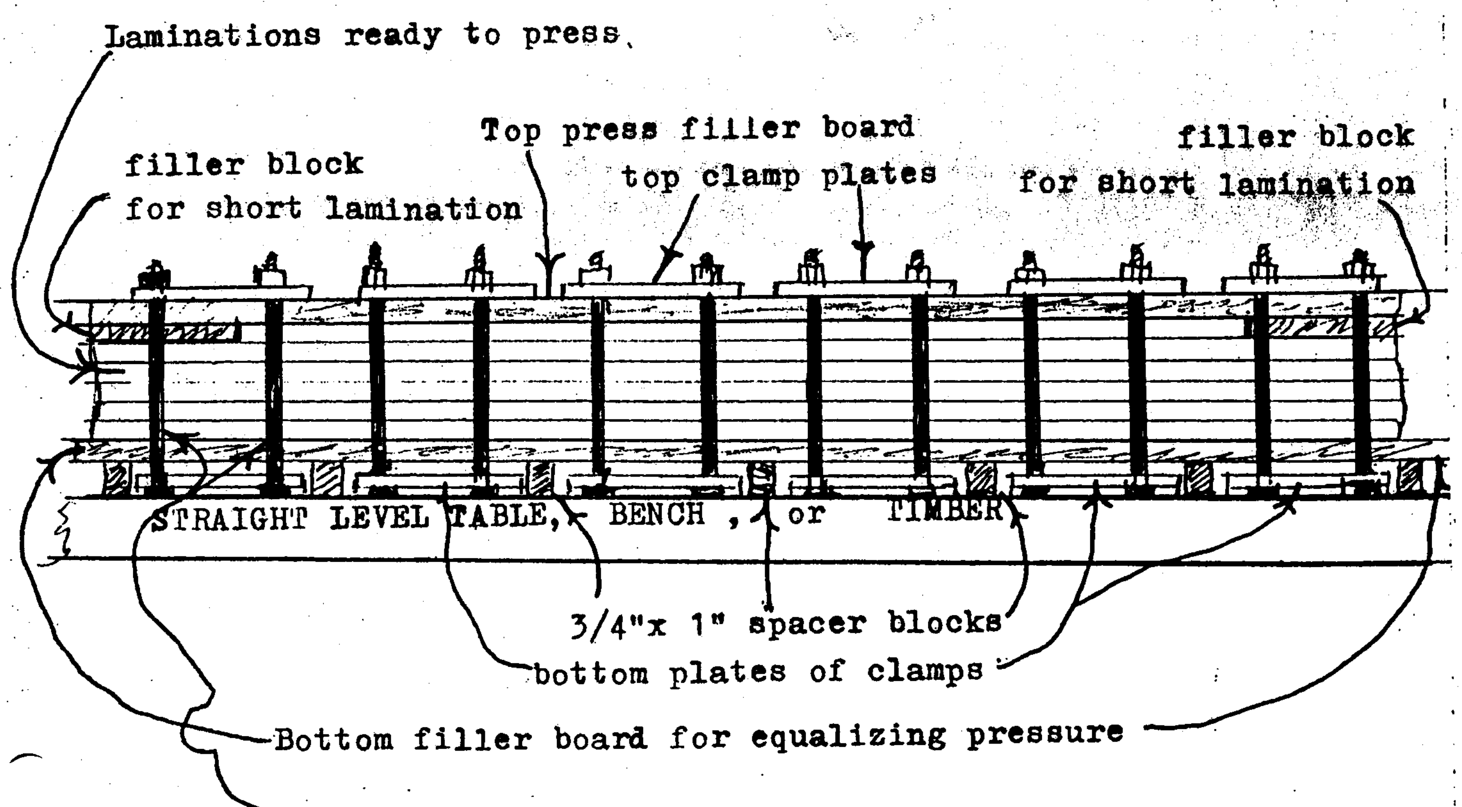
What kind of glue do you use?

I have used casien, rescorcinol, and epoxy glues with satisfactory results. I especially like Elmer's Waterproof Glue (resorcinol). I like the nice dark joints it makes. These darker joints are easier to see and while you are carving they become contour lines and make it easier to get the shapes and curves more uniform. Resorcinol glue requires very good smooth fits between the laminations and good gluing pressure. With epoxy glue, especially when making multi-bladed propellers, the laminatins may need to be pinned or tacked together to prevent the hydraulic action of the slippery, viscous glue from causing the individual laminations to squirm out of place when the clamps are tightened. It is a good practice to do this on multi-bladers when using other glues. Put these pins just inside the circle of the hub flange, and at the very tips of the blank so that they can be sawed off before the blades are carved, thus saving your cutting tool from nicks.

How I make propellers.

Gluing up the propeller blank.

Because the glue joints in a propellerblank make very convenient base lines and contour lines it is important that no bends or twists should be built in when the gluing and pressing is done. The following is the method I use. I lay the bottom halves of my clamps on a very straight level bench or table as long as the propeller is going to be. If no bench or table is available ,a good heavy straight piece of timber might do for a two blader,but for a 4 blader I must have a table. Between the clamps (crosswise) I put pieces of 3/4"x1" about 8 inches long. This is to support the bottom board in my stack of laminations at uniform height from the table because the plates in my clamps are not all the same thickness. I hope this drawing will enable you to understand what I mean. It shows what things should look like just before the bolts on the clamps are tightened.



At least 25 - 1/2" or 50 - 3/8" machine bolts for a six foot propeller. Start at the center and work toward each end when tightening. go over them about 3 times pulling as hard as I can with a 1 ft wrench the last time around.

How I make propellers.

Gluing the laminations.

I use this arrangement of grain and glue joints

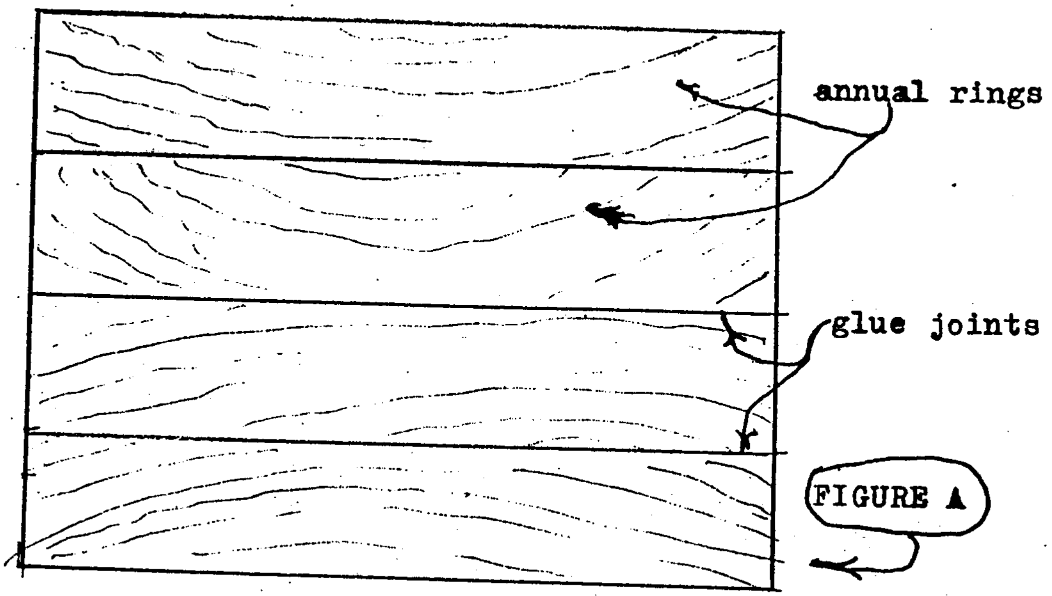


FIGURE A

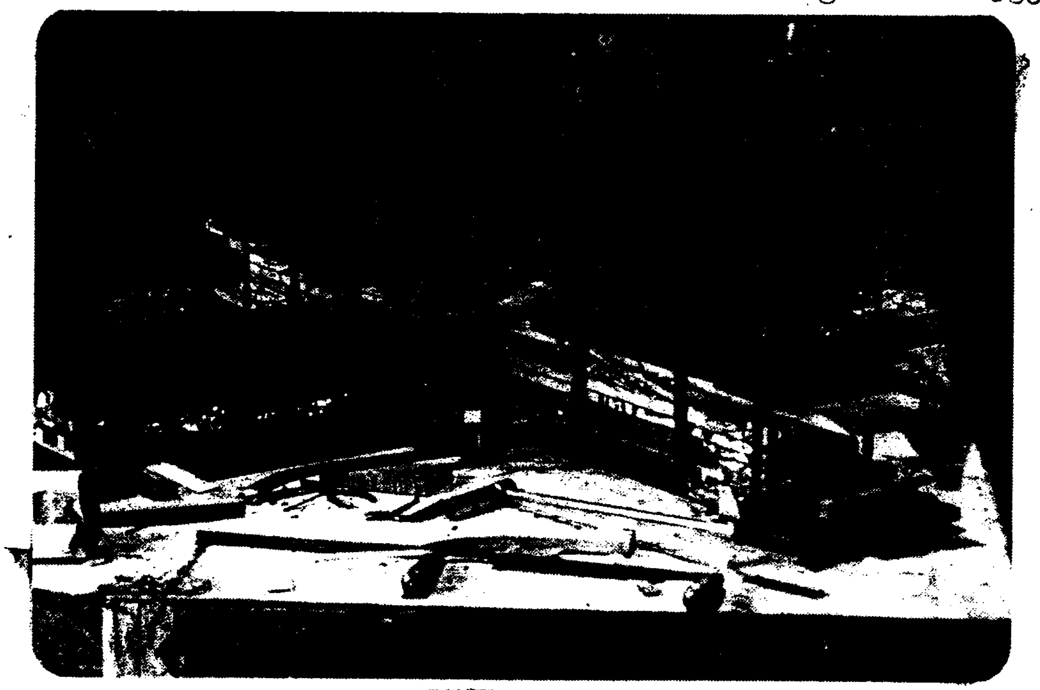
when I put my laminations into the clamps for gluing. You will notice that in my arrangement the side of the board which had been toward the outside of the tree when it was growing now is toward the inside of the propeller. I put them this way because as lumber ages the outside of the board tends to shrink more than the inside, giving it a tendency to cup in that direction. This way of arranging the grain is usually followed in furniture making. At any rate, I have never yet had one of my joints in a propeller come loose.

I like to have long enough bolts in my clamps so that I can put one board in the clamps before I start laying in the laminations. This will help to distribute the pressure of the clamps more evenly and helps prevent local crushing of the laminations that otherwise might take place. A piece of plastic or waxed paper will prevent the "squeeze out" glue from sticking it to the finished blank. An extra board should be used between the top lamination and the top of the clamps for the same reason.

Epoxie glue is very useful in repairing minor damage to tips leading edges etc. because it does not require such severe clamping pressure as other glues does nor does it require such perfect fits.

How do you clamp the laminations together?

I do not use C clamps for clamping my laminations together. I could not afford that many. I use clamps made from plate steel bought at a salvage yard years ago when I was gluing up a spar for project I started and abandoned some years before I started on "Die Fledermaus" The picture below show how they look when holding the blank for a 4 blade prop. Those bolts are 1/2" X 6 inches long. They have been pulled up with a force of about 90 ft lbs. That's almost enough to start stretching the threads. That blank is about 54 inches in diameter. Those plates range from 3/8 to 1/2 inch thick. There are 29 bolts there. The wood is fir. The glue is resorcinol.



I think that this is the best method of clamping when gluing blanks for airplane propellers. A few days ago a friend and I glued a blank for a prop for a 150 HP Lycoming. It was 74 inches long. We used these same clamps. We had 14 bolts on each side and one through the center. We used a ratchet wrench 12 inches long and pulled them just as tight as we could. We tightened them like we would have tightened the cylender head bolts on a car. We started in the center and worked both ways. We only pulled them up snug the first time around. Then we went over them 3 more times til we had as tight as we could get them with that size of wrench.

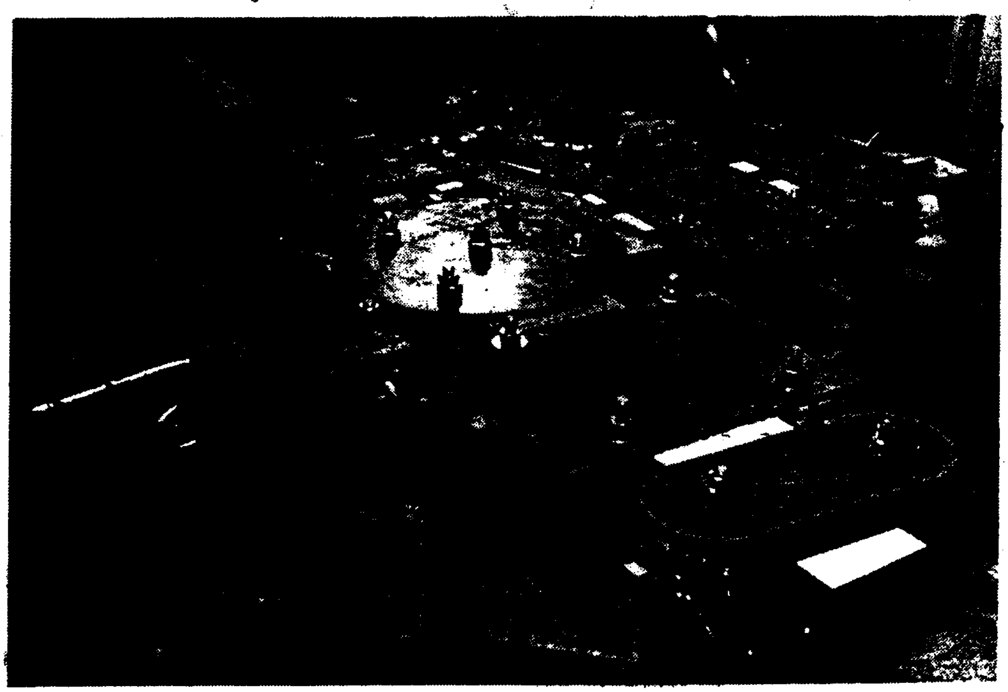
How I make propellers.

What we were trying to do here was to press these layers of wood and glue together with a force of about 150 to 200 lbs per sq. in over the whole surface of the blank and to exert this force as evenly as possible. When you figure out the amount of pressure needed to do this it comes out to about to 27 to30 tons. We had 29 bolts there so that is about a ton to the bolt. I would say from my experience that the equipment shown in the pictures does it about right. One must use a little discretion here,(some people don't have any). Don't crush the wood in the blank, but do have it tight.

Now some may ask if this gluing should be done before the laminations are cut out to the shape of the front view of the propeller or afterward? I have done it both ways. If they are cut out beforehand a little more care must be taken, but you will need just a little less glue. One often finds that one or two laminations can be a little shorter than full length. If so, that is the way I make them. When I when I do this I use some pieces of scrap lumber to fill out the remaining spaces so that the clamps will pull everything up tight.

I try to think this matter of gluing through very carefully all e way. I get my clamps all ready, and arranged in place, and make what I call a "dry run". First I put a piece of scrap lumber(full length and width and smooth),into the clamps. Then I lay the individual pieces which I have prepared,into the clamps in the order that I want them, with side up that I want up. I put them together so that the side of the board which had been toward the outside of the tree when it was growing, is now toward the inside of the blank. Figure A on page 27B shows what Imean. I do this to minimize the strain on the glue joints as the wood shrinks from age or from drying. I have never had a glue joint on any of my props open up yet. As I lay the lamination into the clamps during this "dry run" I number them and mark which side is to be kept up, and whether glue is to be smearedonit or not.I use a ball point pen ,or a lead pencil for this rather than a wax lumber crayon. If one or more laminations are less than full length, I cut spacer blocks to fill the gaps that are left. I put a piece of plastic or wax paper between these spacerblocks and the laminations so that the glue that squeezes out does not stick them anything. When all the laminations are in the clamps,I put one more board on top of the laminations that are in there to fill out the space. Then I lay on the top parts of the clamps where they belong and screw on the nuts, but I don't tighten them. I make sure that the nuts will all go on with my fingers without binding,(this is a good thing to do before one lays the clamps out in the first place, but if I didn't do it then I do it now). I also make sure that the laminations in the clamps are going to be pulled up as tight as they must go before the threads on those bolts are all used up. It may be necessary to put an extra shim in on top of the laminations so that this will occur. The board I put in on the bottom and the one one the top help to prevent crushing if the laminations are of rather soft wood. I make this "dry run" to be certain that once I start glue-ing that no hitch is going to develop which could delay the suc-cessful completion of the process. If everything seems to be O.K., I take it all apart again, laying each part out in proper order, so that when I assemble it again, no mistakes will occur. For the glue-ing process I pick a time when no interruptions are likely to appear. I. it is cold weather, I make sure that the wood is warm and the room in which I am to work can be kept warm(70 degrees) for the next 18 hours. One reason that I am so fussy about getting everything so surely ready before starting to mix the glue, is that all gluing involves two critical periods of time. The first is called the"open life". This is the length of time betwen the moment you start speading the glue, and the time when the clamps must be tightened. The second is known as " pot life". This is the length of time between the mix-ing of the glue and moment it begins to set in the pot. Neither of these "times" can be exceeded without adversely affecting the qual-ity of the joint. When the temperature is much over 70 degrees F these lengths of time are shortened considerably. I always make sure that I have on hand more than enough glue to complete the job, because I have found that sometimes it took more than I had expected it to. It is bad enough to have to stop to mix more glue, but to have to go to the store to get more would be a calamnity! When I mix the glue I try to mix enough to do the whole job. I use a cheap paint brush to spread it. I don't use a good one. A good one won't be good any more afterward even though one washes it out right away. Not for painting anyway, perhaps it may be O. K. to use it again for gluing.

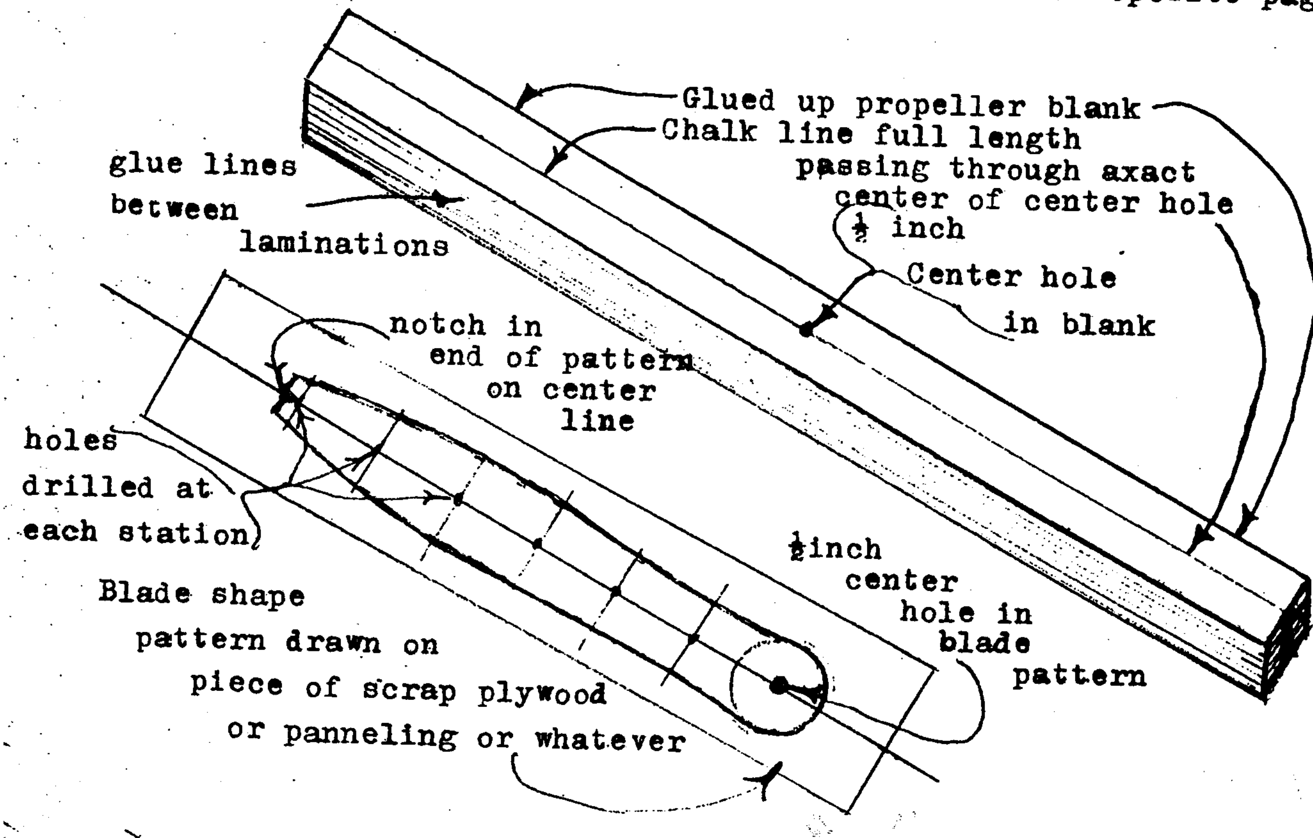
I spread the glue on both of the surfaces to be mated. I try not to be stingy with it. If by the time I have the second surface covered the first one has a few dry locking spots on it , I give them another dab. I don't want a poor joint just because I was stingy with the glue! I try to work carefully and systematically without wasting time. I make sure the parts go together the way they were intended to. I wear old clothes while doing this job, because it is very easy to get glue on them, and if it is not washed out immediately it will never come out, maybe not even then. When I have the laminations all glued and in place, and the blocking in where it is needed, I look everything over once more,and then put on the clamps and tighten them up in the manner described earlier in this desertation This done , I wash the brush and my hands and maybe the container in which I mixed the glue. This is another thing I like about resorcinol glue, any way the brand that I use, It washes off and out easily with cold water if you do not wait til after it sets.

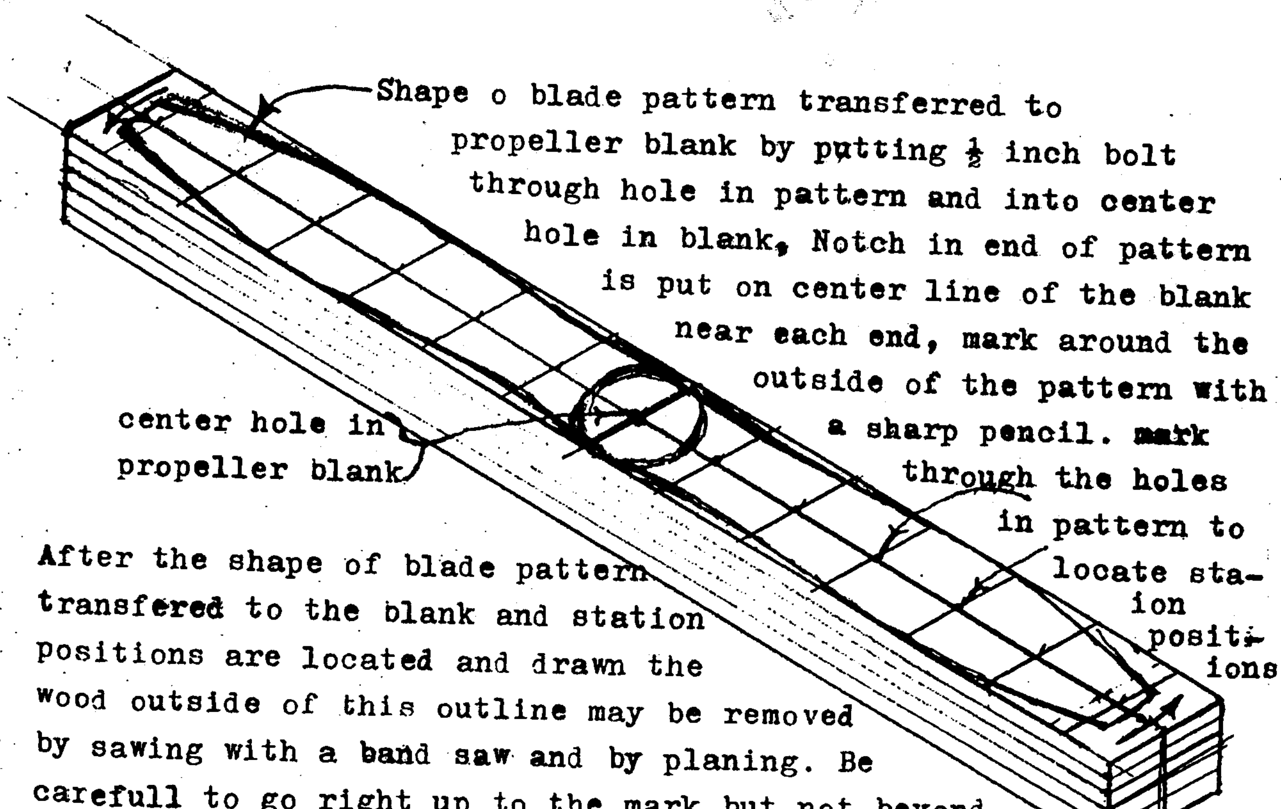


If I remember to put just a little grease on that bolt that goes through the center it comes out easier when I take the clamps off. Quite a job this gluing a propeller blank, but no worse than writing this stupid book.

How I make propellers.

Laying out the propeller. See text on oposite page.





After the shape of blade pattern transfered to the blank and station positions are located and drawn the wood outside of this outline may be removed by sawing with a band saw and by planing. Be carefull to go right up to the mark but not beyond. Keep the edges of the blank square with the face by checking often with a trysquare.

How I make wood propellers.

I take the clamps off the day after gluing. If the weather is very cold I take the blank into a real warm room and let the glue set for another day. Sometimes I clean it up during this time, that is, I rasp or plane the squeezed out glue off the side to make it look a little better, but I try not to make a religeous ceremony out of it. At this stage I am not interested in the edges of the blank, but in the front and back faces of it. I lay it on the bench with the front side up and draw a straight,--and I mean a straight line from end to end right through the center hole using a chalk line or a very straight straight-edge. I get this as nearly perfect as I can because if one is sloppy here, it can cause trouble later when balancing.

When this is done I find or have at hand a piece of plywood or other suitable material and make a pattern for marking out the shape of the hub and the blades and for locating the positions of the stations on the blades. To do this I use the information from the list of specifications I have previously developed for the particular prop I am carving. An example of one of these sets of specifcations is shown on page 67B.

The line(on the specifications), marked Radius tells me how far from the center of the hub each of the stations are to be placed. The line marked Width of Block tells me how wide the pattern is to be at each of the stations. I draw a smooth line connecting the points I have thus located. The result is something that looks like the outline of a single bladed propeller. This I saw out on a bandsaw and plane down right to the line. I drill a 1/2 inch hole in the center of the hub and cut a sharp notch right on the line at the center of the tip. The center sketch on page 31A helps to explane what I mean. I like to have my pattern extend about one inch beyond the No. 6 station. I then drill a 3/16 inch hole right on the center line at each of the stations. A 1/2 inch bolt is then put through the center hole in the hub of the pattern and into the center hole of the propeller blank. Then I put the notch in the end of the pattern right on the line that runs down through the center of the propeller blank. A sharp pencil is then run around the outside of the pattern. The pattern is then rotated 180 degrees and the process repeated. The positions of the stations are located on the center line of the blades by marking through the holes drilled through the pattern for that purpose. All of these operations are illustrated on page 31A facing this page.

How I make wood propellers.

Still laying out the blank.

After the shape of the blade pattern is transfered to the blank and the positions of the various stations have been drawn in, I saw out the blank to shape on a bandsaw, being careful not to go beyond the line, but to go right up to it. A good sharp blade is a big help here. It is also helpful if the guides on the blade of the saw are well adjusted. After finishing the sawing, I also resort to planes, rasps, and a spokeshave to get the blank into the shape I want. I try to keep the sides of the blank square with the face, so I use a try-square often to check the squareness.

When I have completed this task to my satisfaction I turn the blank on edge and with the help of a trysquare extend the positions of all the blade stations onto both sides of the blank. If I have not already done so, I now carefully determine which way the propeller is intended to turn, and mark it plainly on the blank so there will be less likelyhood of a mistake being made later when the actual carving begins. When I thus have the blank lying on its side I decide, after again checking the direction of rotation desired, which of these blades will be moving toward me and which one will be moving away from me, and mark them. At this point I note from my plan which of the glue joints is to be used as the base line from which to locate the leading and the trailing edges of the blades, both at the station next to the hub, and at the station at the tip. I measure off and locate and mark these positions directly on the blank as accurately as I can. I mark the position of the trailing edges on the blades that should be going from me, and the position of the leading edges on the blades that will be coming toward me. These are marked only at the station next to the hub and at the station at the tip. I have not mentioned this before,but when I design my propellers I make the shape of the blade such that both of these are straight lines in one plane and so can be drawn using only a straightedge. I will not go into the mental gymnastics necessary to accomplish this, but I will say that the pitch of the blades at the various stations and the widthof the blades at those stations are involved in it. If one thinks about it hard enough and long enough, he will be able to figure it out. What I use for a straightedge is a piece

How I Make Wood Propellers.

Still laying out the blank.

of thin flat strap iron of the kind that is used to hold together bales of lumber and other materials. One can usually find these lying around sawmills or lumber yards and often at scrap iron dealers. At the trailing edge of the blade I draw the line that should be the exact trailing edge and another one that is 1/16 of an inch below it and one that is 1/16 of an inch above it. This is because I want the trailing of the blade to be about 1/8 of an inch thick, or to state it more accurately to have a radius of 1/16 of an inch. After I draw the lines indicating the leading edges of the blades I also draw the lines shown on the drawing on page 65B marked "Front side of the blade". This line is the highest point on the front side of the blade when the propeller is lying on bench with the back side of the blade down. Layout of the propeller is now complete. Illustrations depicting the various steps in the process are shown on pages 31A and 32A.

Making the blade templates.

The next task that must be accomplished before I can really start carving is to make the templates for the airfoils, then I can safely go to work making the chips fly. I say "safely" because without templates it is very difficult to tell when we are done carving, and we do not want to go too far. I am not going into the advantages of making templates again at this point. I thought I made a pretty longwinded sermon on that text on pages 23 & 24. If you have forgotten what I said there I suggest that you turn back and read it again.

To make my templates I take my drawing of the airfoils and the angles they are to be set at, of the particular propeller I am carving, (For example see pages 65D and 65E.),to a photo-copier and make copies of them. Then I find (beg, buy, borrow, scrounge, or otherwise acquire) some sheet aluminum somewhere between .020 to .050 in thickness. It need not be of aircraft quality nor does it have to be all in one piece. Commercial grade stuff will work very nicely, as will scraps left from building a metal airplane or an aluminum gas tank. For a template the size of those shown on pages 65D and 65E of this book, I would cut out some pieces about 6 inches long and about 4½ inches wide. Then I bend up (or down) at 90 degrees a flange 1/2 inch wide and 6 inches long. I make this bend nice and neat and accurate. Now I take that Xerox copy

Go To Page 35

How I Make Wood Propellers.

Making templates.

that shows the airfoils and their angles and cut it into three pieces along lines paralell to the base lines of the angles of the airfoils. I then glue these three airfoil drawings onto three of the previously cut and bent pieces of aluminum so that the bottom side of the airfoil is toward the flange and the base lines of the angles are axactly paralell to it, (see illustration on page 34a), with the trailing edge of airfoil about 1/2 inch from the flange. Not at all difficult is it? If you do not understand it read it over again and look at the illustrations some more. I use this method with all six airfoil stations of the propeller. Now I get my straight cutting tin shears,(if I can remember where I left it), and cut the sheet of metal with the drawing glued to it, right in two along the chord line of the airfoil (the line that runs from the leading edge to the trailing edge). After this is done I carefully cut with my curve cutting shears along the top and the bottom lines of the airfoil and discard these two little scraps. A half round file is used to smooth up any little nicks, but I try to keep just as close to the lines as I can. The illustration on page 34A (opposite), and page 39 (ahead) show what they should look like.

Well,--- now those templates are done. Now we can get down to the real business of carving.------,Or can we?-----? welllll---ll, maybe not quite.---. If I remember correctly someone said,"What tools do you use?" and "Do you use power tools? and if not why not?"

My answer to this is: Yes I use tools in the process of carving,----mostly hand tools, because with hand tools I cannot make mistakes quite so quickly. One thing that I find that comes in very handy, and which I made myself is not really a tool as we generally think of tools, but a fixture, or a kind of a stand which I clamp to my workbench and can use to hold the propeller I am working on in any one of a number of advantageous positions for the paricular job I am doing. It is not absolutely necssary,-- only helpful,-very helpful. I can get along without it though, I carved my first VW propellers while they were bolted to a verticle 6 X 6 timber (post) in the haymow of my barn.

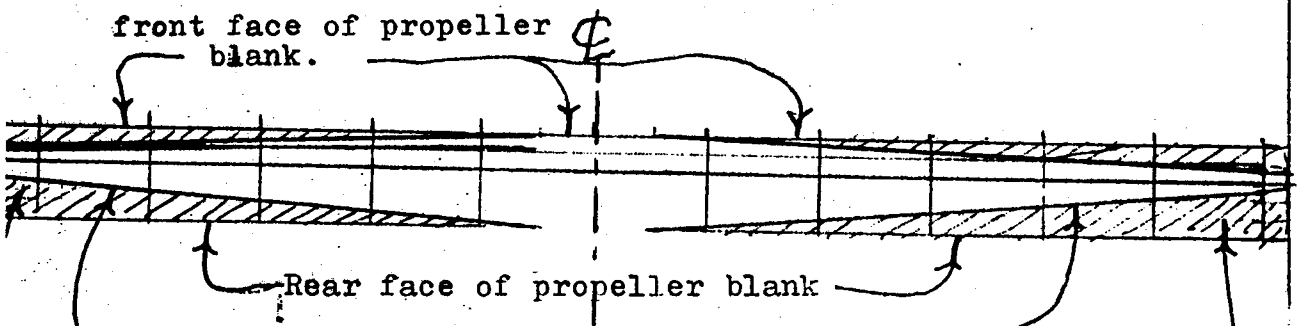
First then after this fixture I would list such obvious things as the measuring tools; rulers, squares etc. , then some kind of a saw, hand saw? band saw? table saw? skill saw? radial arm saw? I use the

the first three, which I have. Next, I have cutting tools. At least that is what they are supposed to do. They include a drawknife, or a drawshave, whichever you please, a spokeshave,(origonally a wheelwright's tool), most hardware store clerks don't even know they exist, or at least claim that they do not, and a good block plane.

Then I have some gnawing tools. These are the rasps and the files. The coarse half round wood rasp is the most useful of these. A new sharp half round metal file is also quite good but it plugs up rather quickly. I often use this file to smooth up the rough rat-like work done by a rasp. When wrapped with sandpaper it is especially good for this. Sometimes I use a large round(rat-tail) file in this way also. Sandpaper is also used quite extensively with a wood sandpaper block for finishing. Remember, this block need not always be square, for some special purpose it could be curved on one or more of the edges or sides. Sandpaper comes in many grades(degrees of coarseness) and types. It is classed as an abrasive(it cuts by scratching). It should not be used until all the work to be done by the cutting tools is completed. This is because it leaves little particles of itself imbedded in the surface upon which it has been used and these little particles tend to dull the edge of a cutting tool used later on that same surface.

I also have a real handy little power tool in this "abrasive" class (expensive too), but I do not recommend it. It is a little 5 inch electric angle grinder on which a very coarse sanding disc can be mounted. You say that must be a toy?- No it is not a toy! It runs at 10,000 RPM and really eats the wood away. I used it almost exclusively in carving two four bladers, one from fir (a very ornery wood) and the other from "ribbon" mahogany,(fully as bad). This is is indeed a very efficient little tool but I do not recommend its use. Why not? Because unless you have much better respirators and goggles than I had, it is a hazard to health and eyesight!! Even though I worked outside and tried to arrange it so that the wind was in my favor, I coughed and spit and wiped my eyes for a week or more afterward. Perhaps you think,"Well, that wood dust shouldn't be so bad." Perhaps that "wood dust" <u>might</u> not not be-, but how about that epoxie, resorcinol,-or what have you, pulverized waterproof,boilproof,rotproof glue that you are breathing in and getting into your eyes???-- No,-- for that reason I do not recom-

How I make propellers.

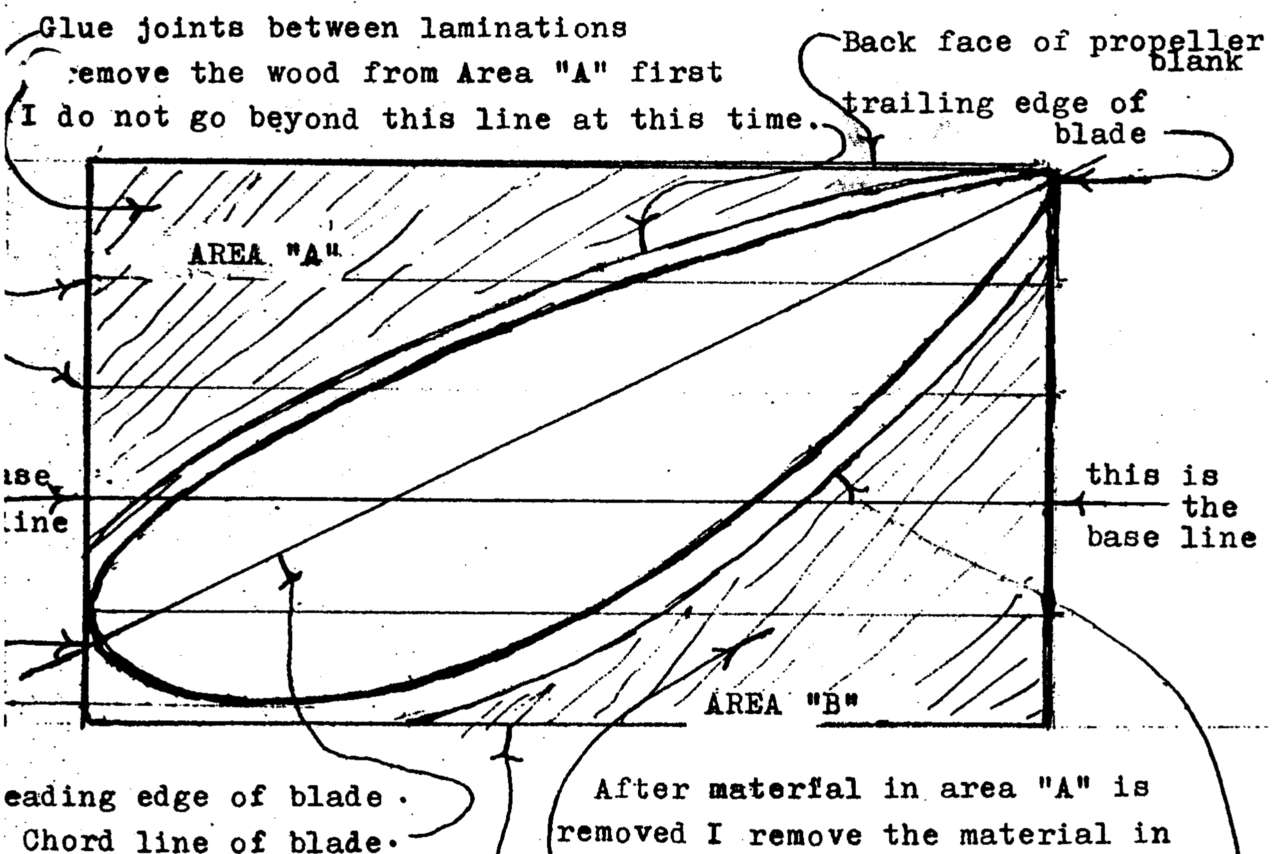


I remove the wood in this shaded area first
being careful to stop 1/8 of an inch from the line.

I do not touch the front face of the blank quite yet.

****

Below is as cross section of the station next to hub as one would seeit if the blank were mounted with the back face up.



After materal in area "A" is removed I remove the material in Area "B" on the front side of the front side of the propeller blank.

I am very careful not to go beyond this line.

Tools, continued

mend its use.

There is another simple tool that I sometimes use, espesecially when altering a propeller. It is called a contour gauge. It can be bought at many hardware stores. It is used for measuring or comparing the curves of curved surfaces. In our case the airfoils of propellers. Some carvers use this instead of templates to get both (all) blades alike. It is useful when copying an existing propeller or making alterations to it.

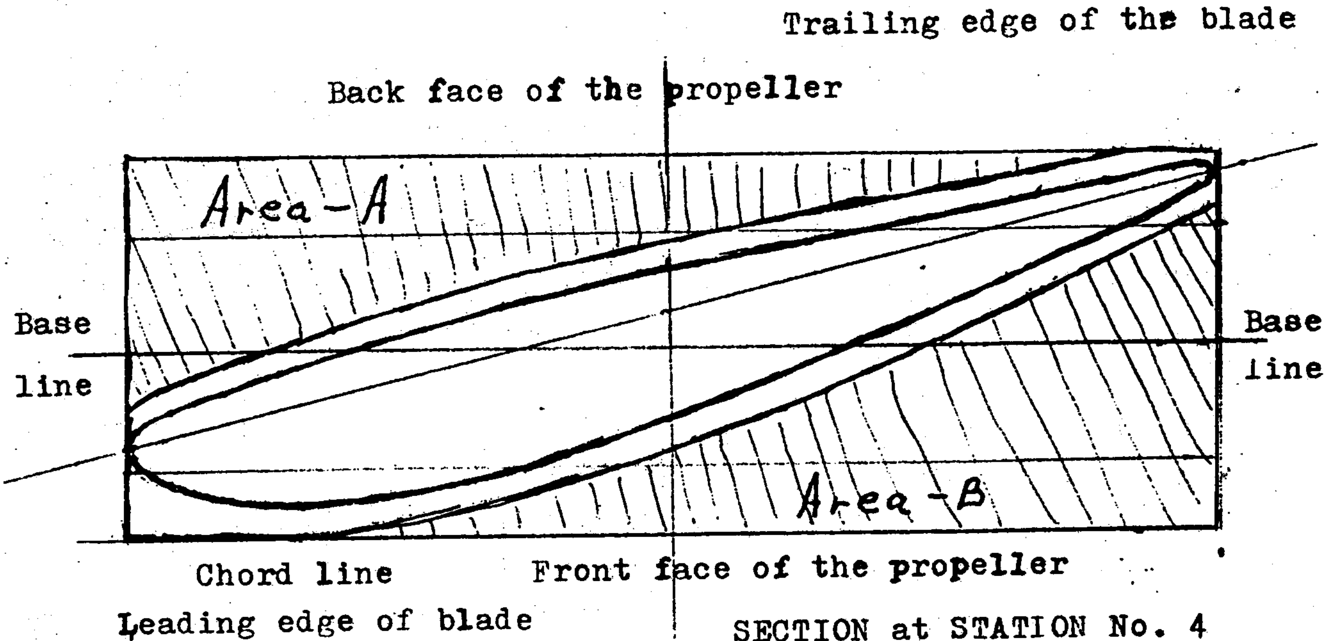
A final tool that I must mention that one need not necessarily own but sometimes needs access to (in some commercial woodworking shop or otherwise), is a thickness planer. No-, not just a jointer, but a machine to plane boards to an accurate specified thickness and keep both faces paralell. For most two blade propellers it is not needed because one can usually utilize the 3/4 inch thickness boards from the lumber yard, but for multi-blade propellers thinner laminations often must be used and their thicknesses must be more accurately controlled. Sometime I hope to own one of these. I dislike going to a commercial shop to get this work done. The man doing the work always wants to know why I want the lumber planed so thin and when I tell him he gets a very agitated look in his eye,- as if trying to decide to call the county mental health center to tell them that one of their patients has escaped or to call his attorney to discus the liability implications involved if he does the work for me and the plane crashes.

Carving

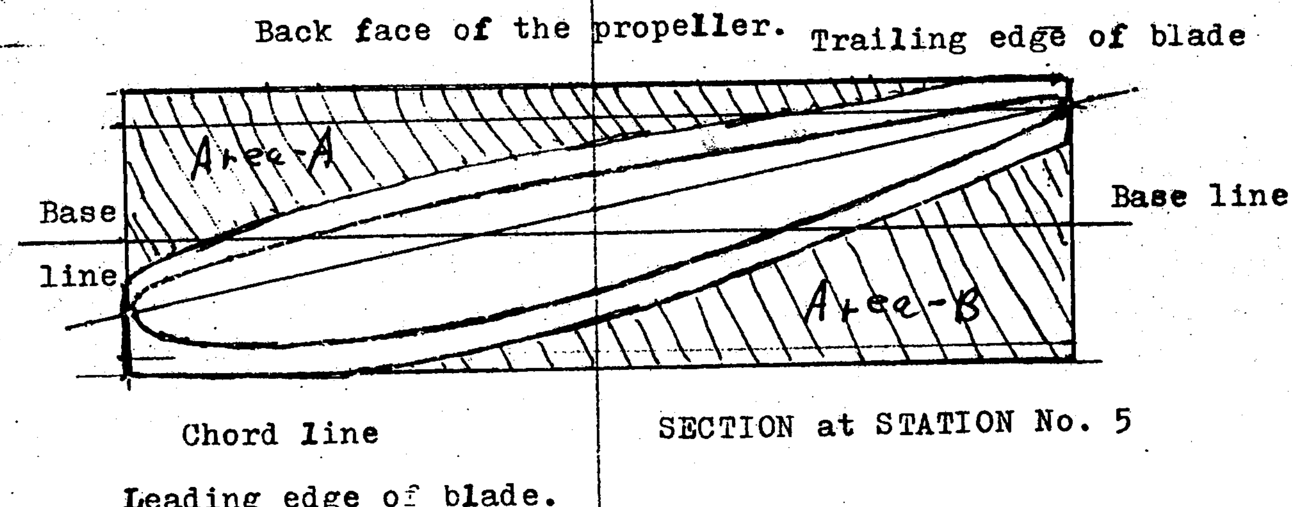
When I start to carve a propeller I start on the back side of the blade, the side of a tractor propeller that is toward the engine. Maybe I ought to draw you a picture. Well yes, I have already done that on the page to your left, page 36A. The illustration at the top of page 36A is very similar to the one at the bottom of page 32A. It shows the side view of a finished propeller. On page 36A I try to show some of the various steps necessary to reach the finished product. Carving a propeller is really a matter of removing from the propeller blank certain wood from certain places. On pages 33 and 34 I described the laying out of the position of the trailing edge of the blade. I remove the wood between this line and the back face of the blank first, being careful to stop 1/8 of an inch from the line. (Go to page 38.)

How I make propellers.

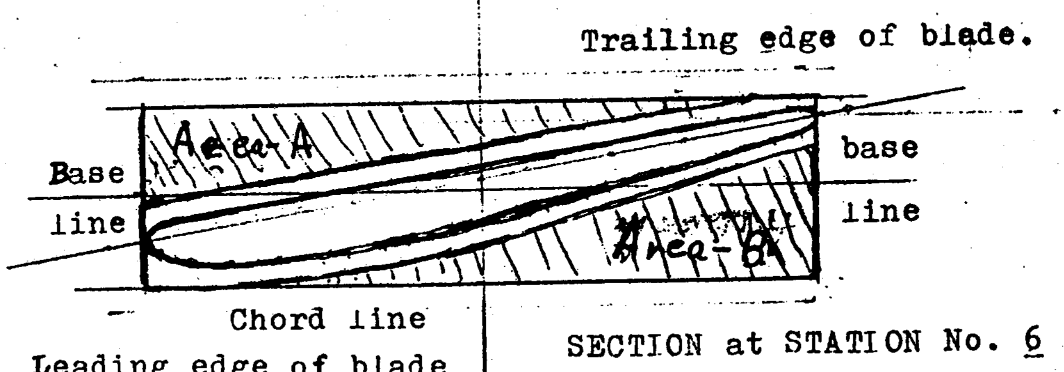
Steps in carving.



SECTION at STATION No. 4

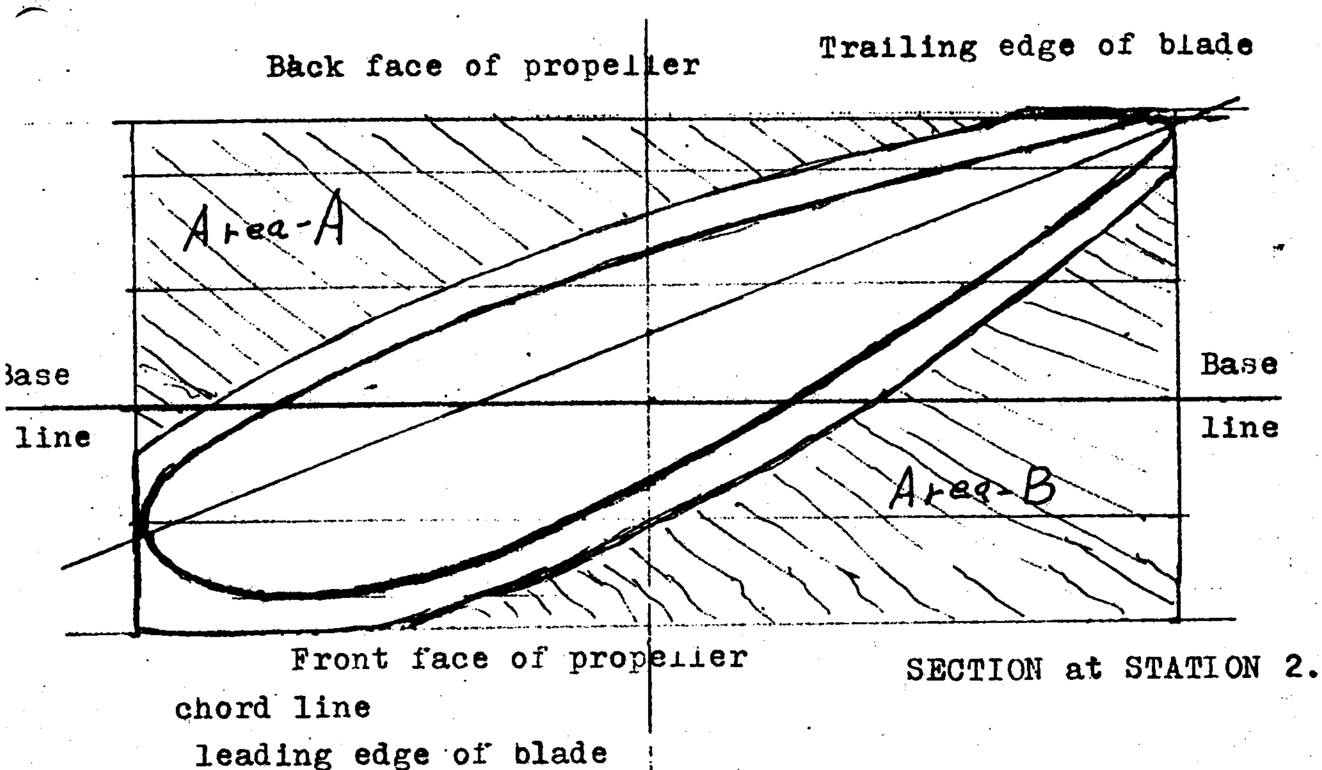


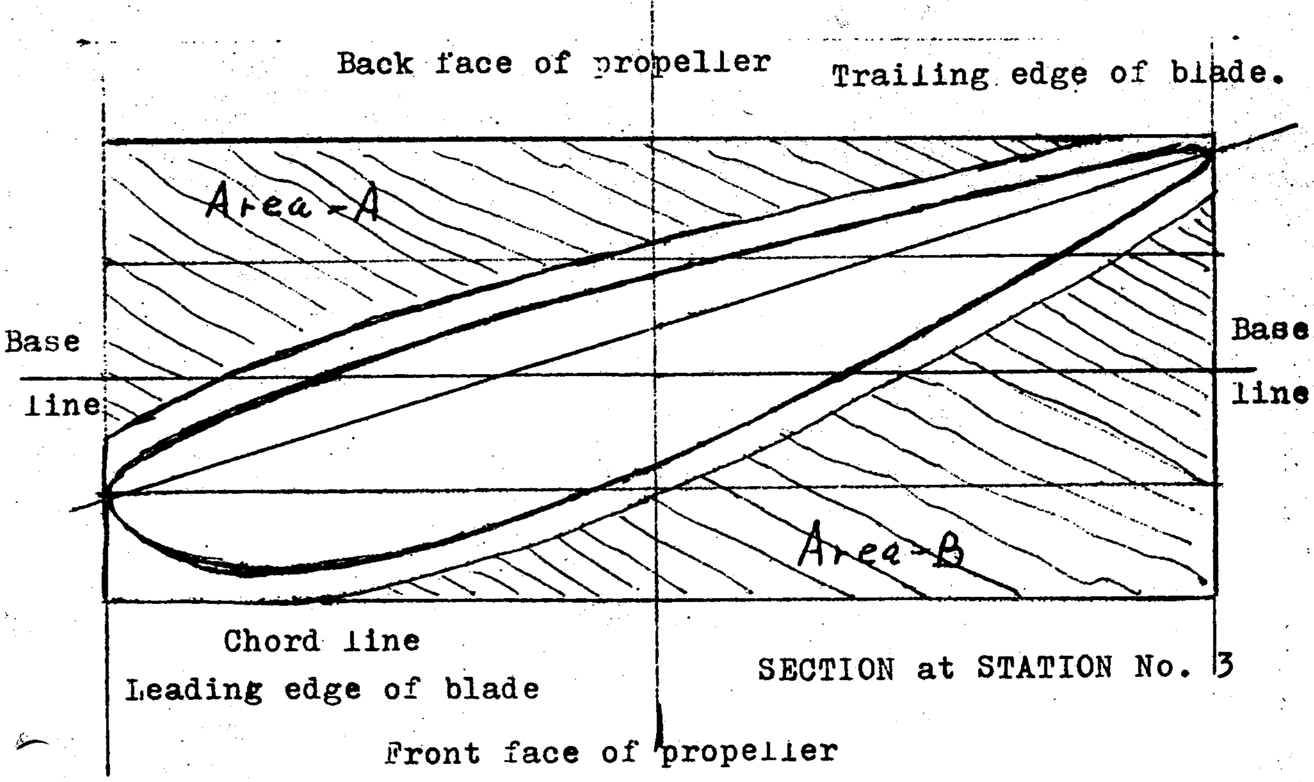
SECTION at STATION No. 5



SECTION at STATION No. 6

See text on page 38 for an explanation of these illustrations.



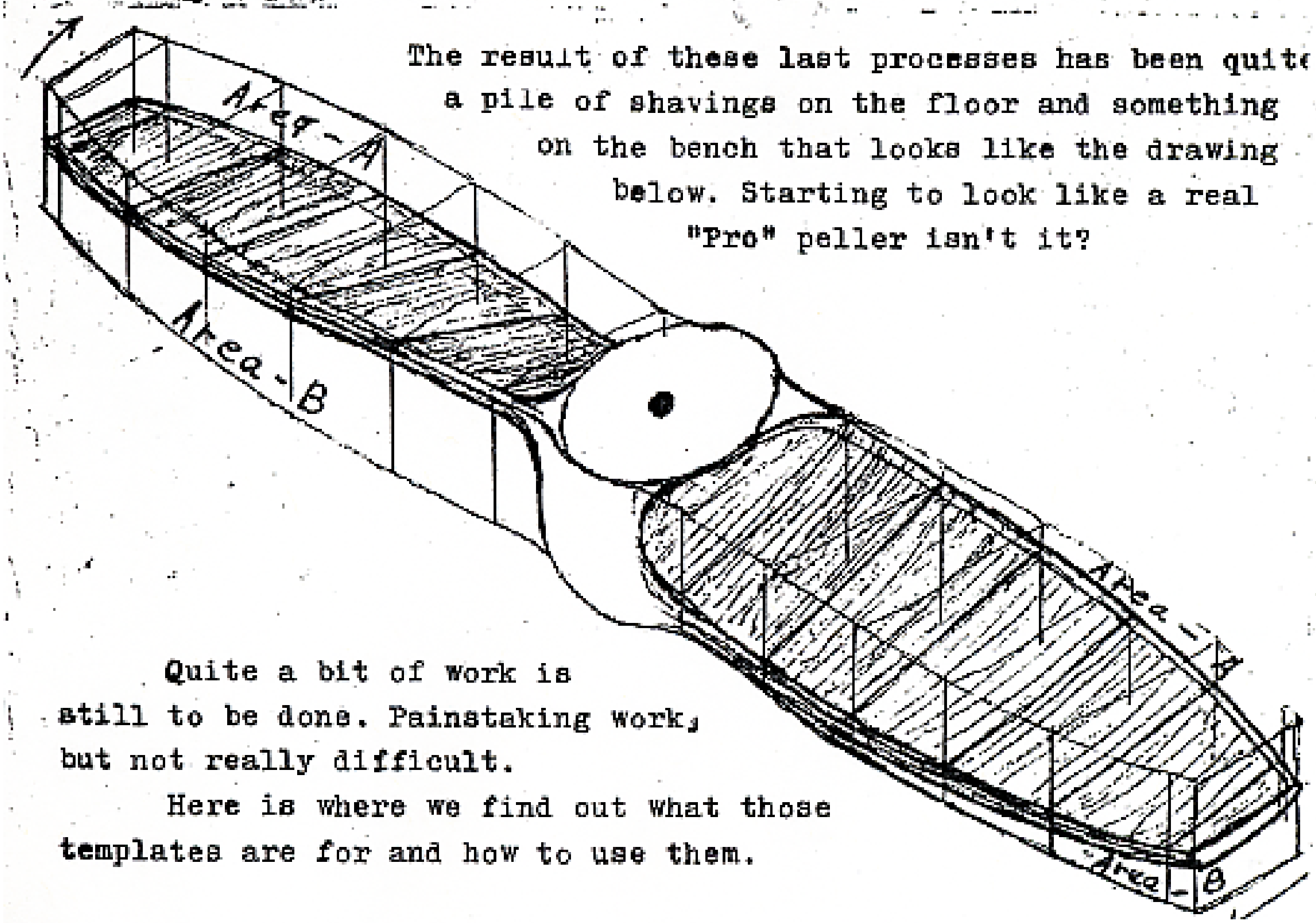


See text on page 38 for explanation of these illustrations.

How I make propellers.

Steps in carving.

This is the part of the blank labled"Area A" on the drawing at the lower part of page 36A and on pages 37A and 37B And 38 . . . I try to stay about 1/8 of an inch away from the finished size so that I do not later find when I am establishing the correct angles on the blades and carving them to the intended thickness that I have already gone too far. After I have removed this "Area A" I turn the blank over so that the front side of the blank is up. I then remove all the wood from "Area B", stopping again 1/8 inch from the finished size of the blade. The reason I remove this "Area B" material from the front side of the blade before carving the back side to the finished dimension is that there may be stress from the gluing process or from some other source locked up in the blade and if the back side of the blade was already finished when the front side was carved this stress could cause the blade to twist a bit, and there would be no way to remedy it because it would be already down to size.



The result of these last processes has been quite a pile of shavings on the floor and something on the bench that looks like the drawing below. Starting to look like a real "Pro" peller isn't it?

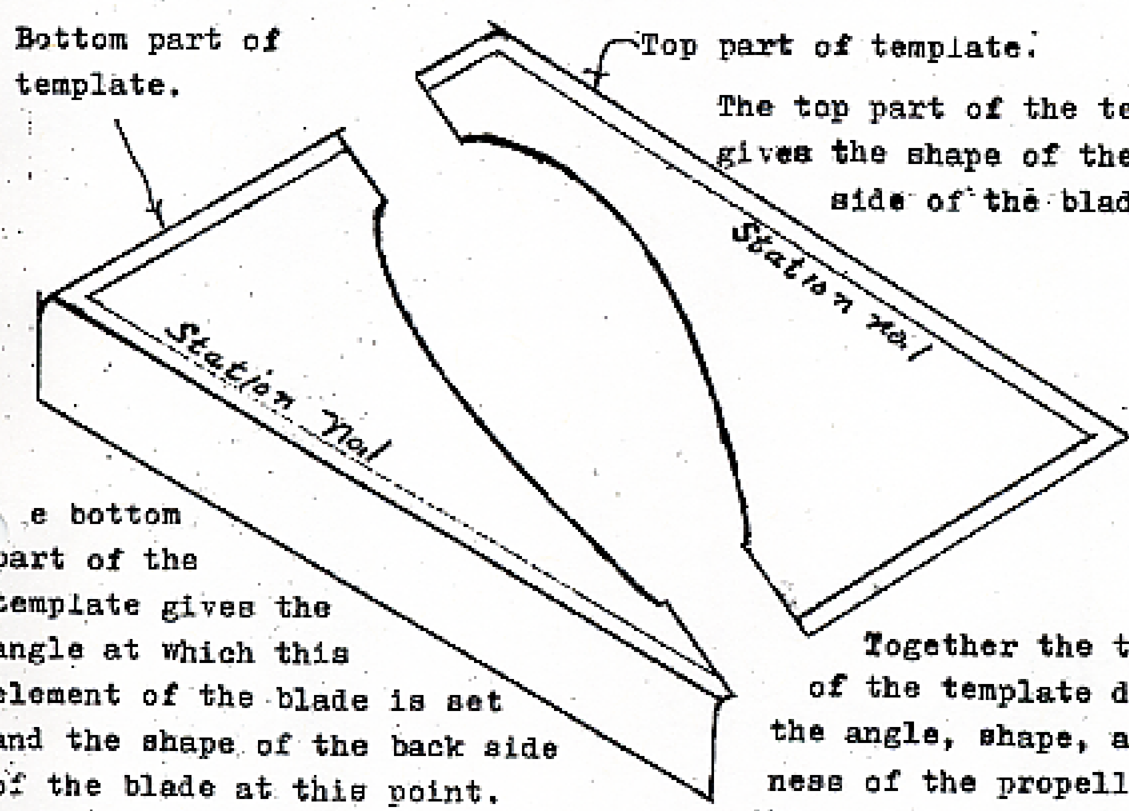
Quite a bit of work is still to be done. Painstaking work, but not really difficult.

Here is where we find out what those templates are for and how to use them.

How I make propellers.

More steps in carving.

The drawing below shows what one of those templates I showed you how to make back there on page 34 A looks when done. I make a set of these,(one top and one bottom,) for each of the stations on the blade.



The top part of the template gives the shape of the forward side of the blade.

The bottom part of the template gives the angle at which this element of the blade is set and the shape of the back side of the blade at this point.

Together the two parts of the template determine the angle, shape, and thickness of the propeller at this point along its diameter.

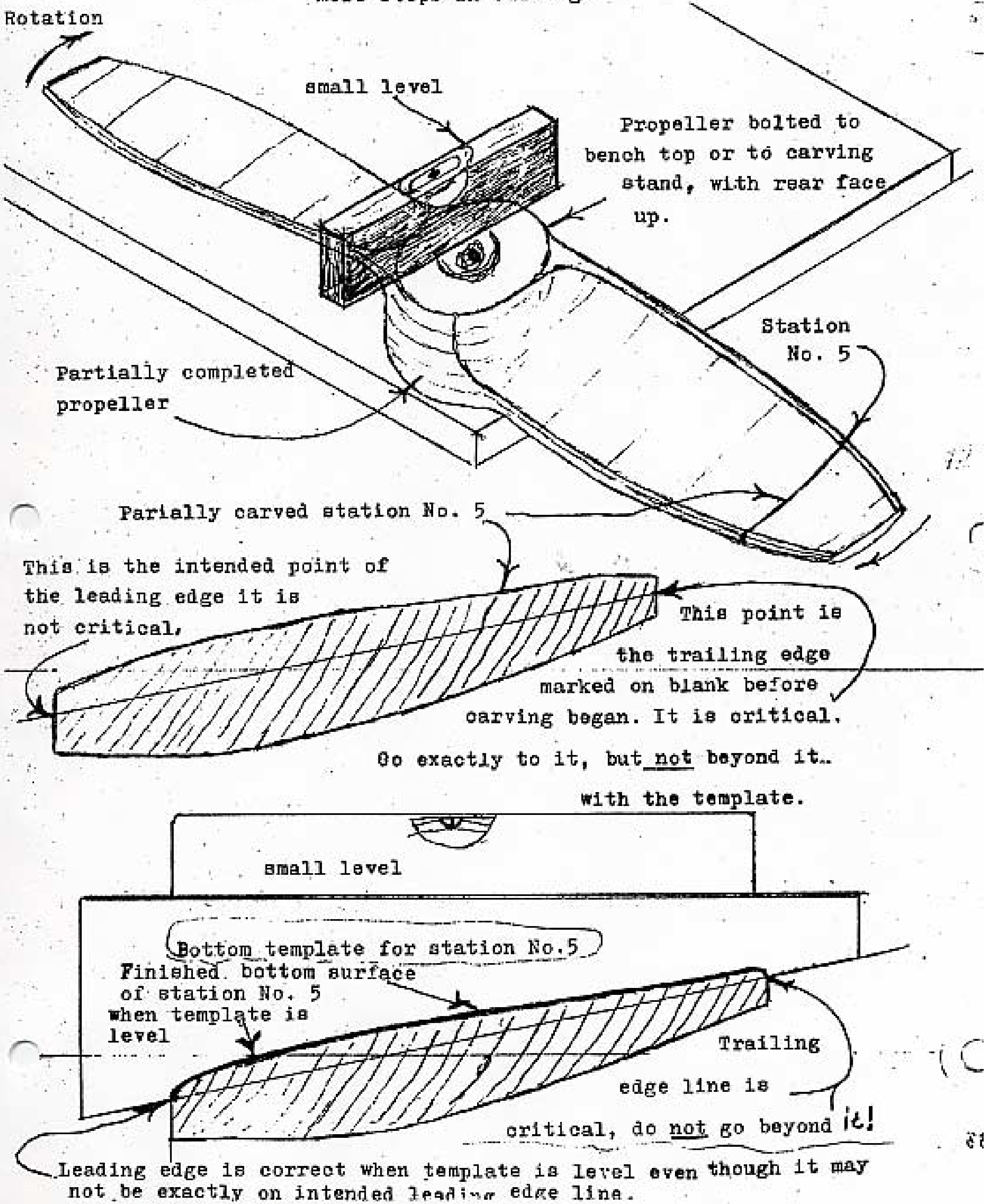
The careful use of templates helps me to produce a more accurate propeller than would be possible without them, and to make more accurate reproductions and variations of them. I believe it is well worth the effort to make them and to use them.

When I set out to establish the pitch angle and the blade shape I mount the rough carved propeller on the bench, or on my carving stand with the rear face of blades up and put a small level accross the hub and adjust whatever needs to be adjusted to make it read level and to keep it that way while I am working on it. I usually begin at the station next to the tip and do that station and when I have that one completed to my satisfaction I turn the propeller one half turn and do corresponding station on the other blade. When that one suits me I go to the next station and finish that one and go to the other blade and do it at that station and the go to the

GO TO PAGE 41 PLEASE

How I make propellers.

More steps in carving.



How I Make Wood Propellers

More steps in carving

(Continued from page 39) next station on that blade etc. until all of the stations on both of the blades are done. This isn't a hard part of the carving process, but it does require patience and careful workmanship. Like many of the other tasks in the building of an airplane the secret is to forget about time and take whatever time it requires to do the job right.

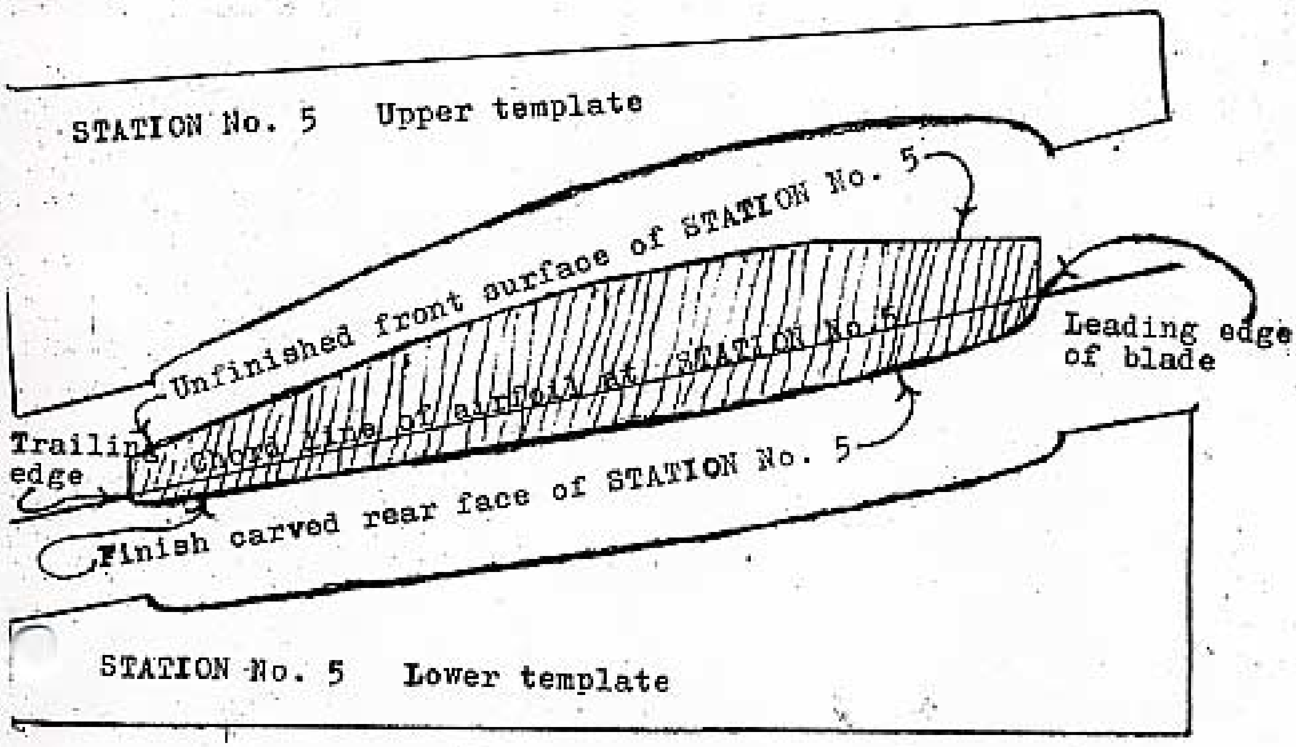
Some of the things I watch are: be sure to keep the back face of the propeller hub level. If I have just turned the propeller end for end so that I can work on the other blade, I check it again to be sure. I watch the trailing edge of the blade to keep it to the line where it was intended to be, and not to go below it as is so very easy to do. Remember,-if one is not quite to the line, he can take off a little more, but if he has already gone too far it is rather difficult to restore it. If the trailing edge is down to the line and the level on the template shows level, I stop there even if the leading edge may not be quite down to the line for it on the blank. Likewise, if the trailing edge is on the line where it should be, and the leading edge is down to its line, but the level on the template does not yet show level, I go a bit further until it does. While I am doing this I continually watch the glue joints on the blades to see if they are forming smooth sweeping lines on this rear face of the blades where we have been working. If they should have a sudden kink in them somewhere it is a sign that something must be wrong. If this happens I stop and find out where the trouble is and remedy it before it so bad that it cannot be fixed. Often I run my hand back and forth along the length of the blades to check how things are coming. When all the stations and the spaces between them on the back face of both of the blades are down to where they should be I unclamp or unbolt the propeller from the bench or from the jig, and turn it over so the front face of it is up. I put my level away for a while. I won't need it while carving the front face of the propeller.

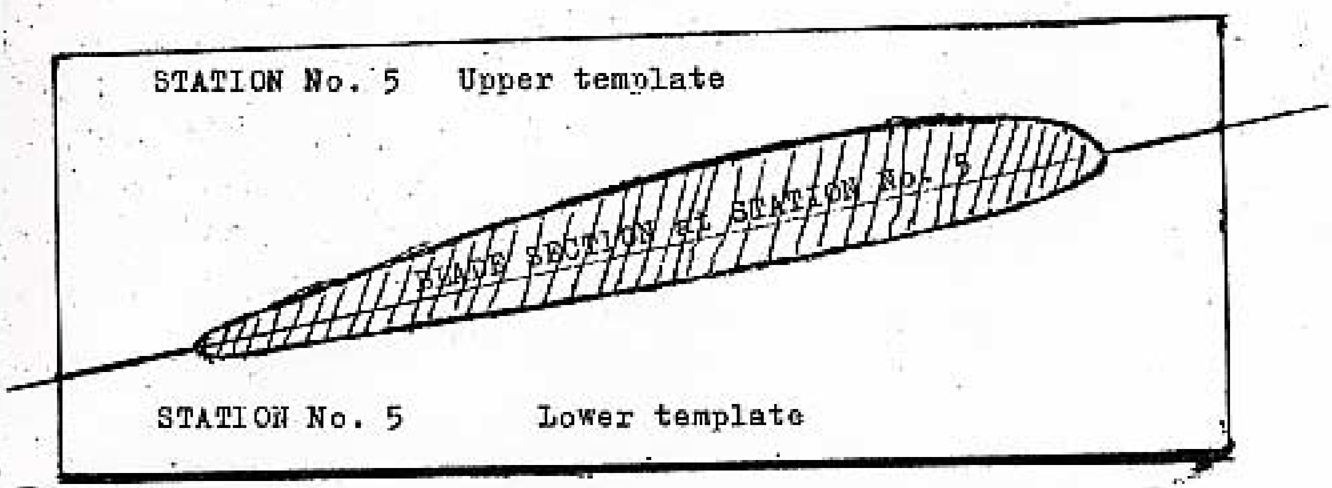
To carve the front face of the blades I need both parts of each of the templates to do it right. Illustrations on page 41A will show what I mean in addition to other things.

How I make propellers.

Still more steps in carving.

Finishing the front face of the propeller.





STATION No. 5 when carving is finished.

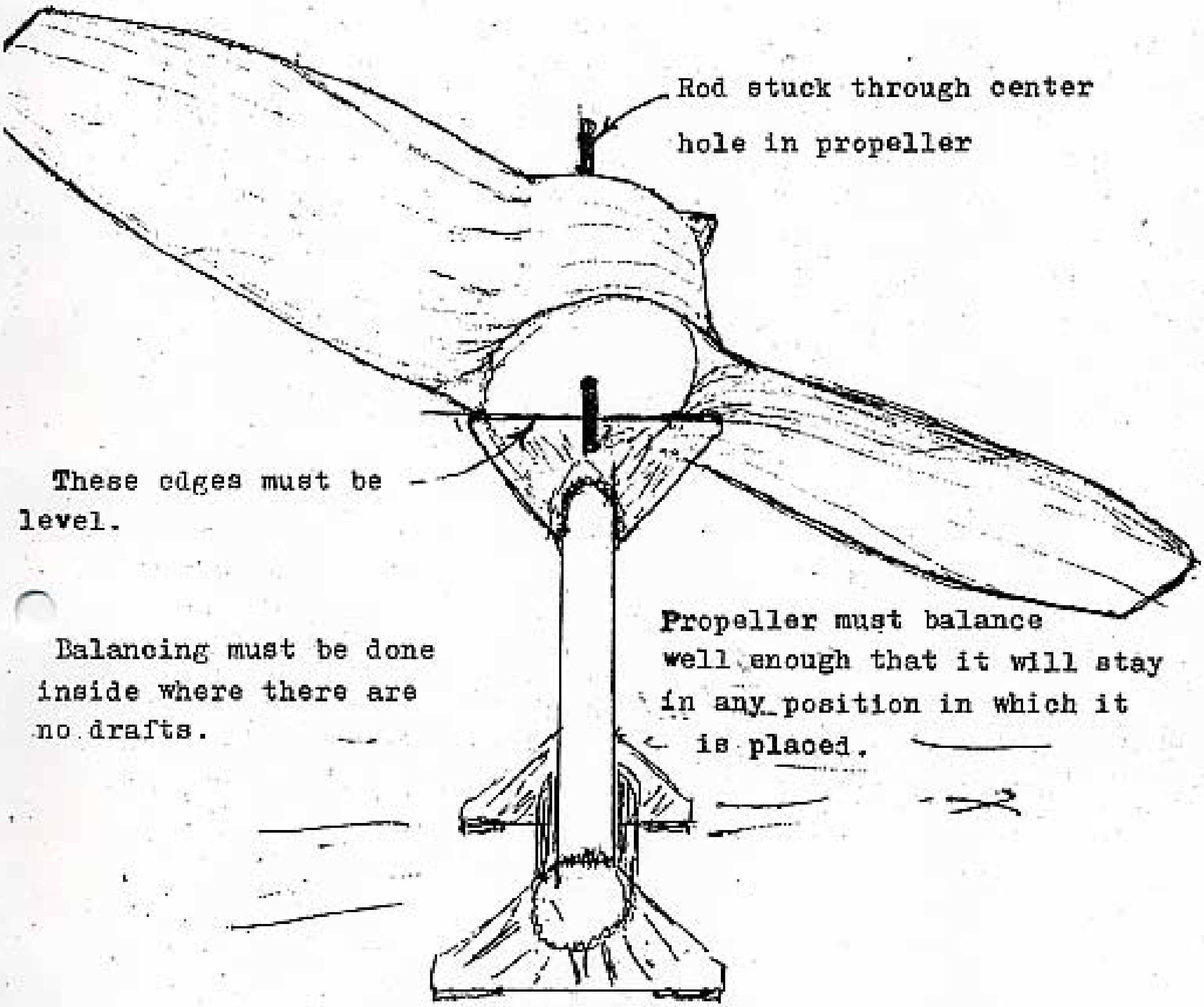
How I make propellers.

Finishing the front face of the blades

When the propeller is mounted with forward face up and I have the templates and tool at hand I am ready to begin the last <u>big</u> carving job required to produce the propeller. It resembles carving of the back side except there is no leveling to be done this time. I just have to carve away the wood from the top side of the blade until the upper template will just fit down over the top of it and meet the lower template as shown at the lower part of page 41 A. The secret here is to be careful not to take off too much at a time. The tool called a spoke shave is the most useful tool here and while finish carving the lower side of the blade also. If the wood has a very ornery grain like fir or that ribbon mahogany this can be quite an ordeal. In that case I might have to go to a rasp to get the job done. With good clear pine there usually is no trouble. The little angle grinder I told you about some pages back worked like a charm in these places but it had the drawbacks to its operation, namely; it was extremely easy to take off too much wood before I knew it, and fine wood and probably what was worse the ground glue dust soon filled the air and my eyes , nose and throat. When the templates have been properly fitted at all the six stations on both blades I then turn to finishing the junction of the hub with the blades. Here I use a half round wood rasp and a half round file. The file fills up very quickly when used in wood so I often wrap a piece of very coarse sandpaper around it and use it that way. The file is really only used to smooth up the very rough surfaces left from using the rasp. The carving jig allows me to mount the propeller with the circle of rotation vertical to the ground or even 30 degrees to it. This makes this part of the work somewhat easier. To get the hub round I have two steel plates turned in a lathe from 1/8 inch plate to the size on the outside that I want the hub to be and with a 1/2 inch hole through the centers. I put one of them on the front side of the hub and the other on the back side and put the propeller on the jig so that the bolt which goes through the center of the prop and holds it to the jig is horizontal. Then I take my trusty wood rasp and go to work on it, and work it down til those steel disks prevent me from going any farther. then I use several different grades of sandpaper to smooth it up.

How I make propellers.

Balancing.



One type of propeller balancing stand.

How I make propellers.

Sanding the blades, and balancing.

Now that I have the blades carved and the hub formed the time has come to get out the sandpaper and go to work in ernest, sanding the blades. I like very coarse sandpaper to start with, the coarsest I can get. I use a block which is about ten inches long and three inches wide ,and 1/2 thick. I have the edges rounded somewhat all the way around but a little more soon the ends to give it a slight"sled runner " effect.

I wrap a sheet of coarse sandpaper around it and holding it lengthwise of the blade I sand crosswise of it, full length and and on both sides of both blades. This takes off ripples from the airfoils on both front back sides. I often run the palm of my hand along the surfaces to note the progress being made. After I have sanded in the crosswise direction enough to get the blades noticable smoother I start sanding them lengthwise making long sweeps from the tip to the hub and back again. When the paper gets dull I put on a new piece. Afterwhile the bumps and the dips and the wrinkles and the gouges left from the carving begin to disappear. This is the time I begin checking the balance.

Page 42A shows a stand for balancing which allows the propeller to turn through a full revolution. It must be used in a room which is free from drafts and it must be adjusted so that the edges that the rod through the center hole rests on are perfectly level. With a set up like this it is possible to balance a propeller so closely that the weight of a small wood shaving will cause it to turn. If the propeller is reasonably accurately made, balancing is usually not too much of a problem . To balance it, one removes material from the heavier blade. This I do carefully checking often to see that I do not remove too much. The propeller should be balanced well enough that it will stay it any position in which it is put. Sometimes balance can be achieved by just sanding the heavy blade but more often shavings will have to be removed with a spoke shave. The more difficult situation occurs when the propeller will balance horizontaly but not but not verticaly. This is the hardest situation to cure. It means that the propeller is heavy on one side or the other rather than on one end.I have cured several of these stubborn cases by taking wood from the leading edge of one blade and from the trailing edge of the other, on the heavy side of the propeller. A couple times I had to put a slug in the hub to do the trick. Twice I have had propellers that have refused to run smoothly even though they balanced well statically. Both were of mahogany. Whether this was a factor I do not know. When a propeller is varnished the balance must be rechecked. If it is off, another coat on the light blade can remedy the matter.

If the hub of the propeller must be counterbored to fit the flange on the engine I do this with a fly cutter in a drill press. I practice on some scrap wood before I attempt to bore the propeller so that the resulting hole is sure to be the right size. The pilot of the cutter must also be the right size. A fly cutter is a rather vicious tool so one must be very careful whenever he uses it.

To drill the bolt holes in the hub I use a template machined from steel to locate them and drill them on a drill press. For my VW propellers I drill them with a bit that is 1/64 of an inch larger than the bolt which is to go though them.

It is not absolutely necessary that the propeller be sanded so terribly smooth before one dares to put it on the engine to run it up but it should be balanced quite well. When a propeller is run up the first time I take special note of the maximum RPM achieved. If I were using an electric tachometer I would certainly have it calibrated,- right on the installation too, not in some speedometer shop. If the tachometer was designed to work when connected to the breaker points of an automobile with a 12 volt battery, that certainly wouldn't assure me that it would show correctly when connected to the stop wire of an aircaft magneto. Once I connected a vacuum tube voltmeter which had an internal resistance of 11 million Ohms,(it was designed that way so that it could be connected into

Testing propellers

any operating circut of a TV set without affecting the operation of that circut to the extent that it would be visable on the screen), to the stop wire of an American Bosch magneto on a six cylender farm tractor. With the engine running at operating speed(about 1300 RPM, this was a 1937 model tractor) this voltmeter showed 70 volts! How is that likely to give a correct reading on a tachometer designed for a 12 volt car? Or on one designed for an outboard motor either? A tachometer that shows 10 percent off will give an error of 30 percent in the amount of power you think you are getting from your engine! For an example from real life, not from some longwinded theory: The propeller described on Pages 67B, 67C, 67D, 67E, 67F, 67G and 67H of this book was flown by Vi Kapler on Bernie Pietenpol's personal Aircamper which has a 164 cubic inch Corvair engine on it. Vi said it turned about 2900 static and in the air went to 3500 at full throttle indicating 100 MPH!! Bernard considered this propeller to be too small(I tell about this on Page 67G of this book), so I made him another a trifle bigger and he seemed quite happy with that one. I brought the first one back and gave it to a man who had a CUBy which he had built from scratch and into which he had installed the 2100 CC Revmaster engine which he had bought earlier with the intention of using it in a KR-2. Said Revmaster engine was advertised by its manufacturer to develop 80 HP. The man had flown the Cuby a number of times around the pattern and then one fine day when I just happened to be at the airport he was too, he took it on a longer flight, in fact, some of the boys were beginning to wonder what had become of him. When he returned he said that he had had the plane to 100 MPH at full throttle, and that the engine turned 4100 RPM at that speed! Well-, I don't want to say that he is guilty of prevarication,- that would be unkind,--- but to say that he might have an inaccurate tachometer is not. To me 4100 RPM top is hard to swallow. The visable performance as seen from the ground looked quite acceptable and the engine sounded like it was going somewhere near the right speed, but not like the figures he quoted.

Therefor:-- Make sure that your instrumentation is correct, otherwise you can't be sure what performance you are getting or what to do to improve it.

Testing propellers

Unless you have verified the accuracy of your tachometer and your airspeed installation, the data you compile from testing the performace of your propeller may not mean too much. Checking your airspeed by flying alongside of some other plane may tell you if yours is faster or slower than his, but his instruments might not be showing right either. Checking your airspeed by flying both ways on a measured course on a map is much better, but ought to be repeated a number of times on different days to average windage etc. When one can be sure of his airspeed and tachometer accuracy he can calculate the advance per turn of his prop. From that he can decide if the pitch and the diameter of his prop are in the correct proportion for best efficiency. Study that table on page 4-A which shows how far two popular factory built aircraft advance for each turn of their propellers. It caculates out to about 7/8 pitch at cruise. After a bit of testing you can make the same calculations for your prop too. If your plane advances about 7/8 of its propeller pitch per turn of its propeller at cruise it indicates that the propeller pitch and diameter are about right. If it goes much farther than that it indicates that the diameter is too large, and if is advances much less than that the diameter is too small.

Occasionally I have seen in stories and in ads in magazines and at Oshkosh specifications for engines, propellers, and airspeeds which just do not seem to figure out. Read again the article on page 20 of January 1970 SPORT AVIATION. Look at the graphs. Notice how quickly efficiencies fall off when the plane over runs the pitch of its propeller! But remember, if the plane is <u>very</u> low powered, the propeller <u>must</u> be pitched for maximum performance for takeoff or it will not fly. If it is amply powered best efficiency will be obtained with a little more pitch.

If one suspects the pitch of his experimental prop to be too great it is very easy to reduce it by narrowing the blade a bit and recarving the back face of the blade, but once this is done it cannot be restored. Sometimes it is wiser to carve a new one with less pitch. One can better compare the results by carving a new one of less pitch. However I used that method of altering the pitch of the first two 4 bladers that I made and I am here to say that it was just what they needed. It may not be the thing to do in your case though....

Testing propellers.

I have had little experience testing propellers other than those I have flown on "Die Fledermaus". On it I make sure that the engine will turn at least 2800 static. "Die Fledermaus" is rather amply powered, therefore if for some reason I might not get quite as good performance as I would like the first time up with a particular fan, I may still make it around the pattern O K. If on the other hand the test plane were just marginally powered, it might be quite a diferent story. I recall that the first four blade prop that I flew had too much pitch, and did not get off nor climb very well. It gave me a kind of funny feeling right after lift off. A good long runway is a very desirable thing to have in any case when testing an unknown prop. For an engine that develops its rated HP at 2700 RPM I think I would want at least 2350 RPM on static runup. To raise the static RPM 100 RPM the diameter of the propeller must be reduced by 1 inch, or the pitch by 2 inches. Comparisons of the performances of two different propellers cannot really be made without the use of a manifold essure guage.

After the propeller has been flown enough times so that the diameter and pitch adjustments have been made, is the time to go to work on a real sanding and finishing job. Fiberglass or other tipping might be added at this time also, plus a good balancing job.

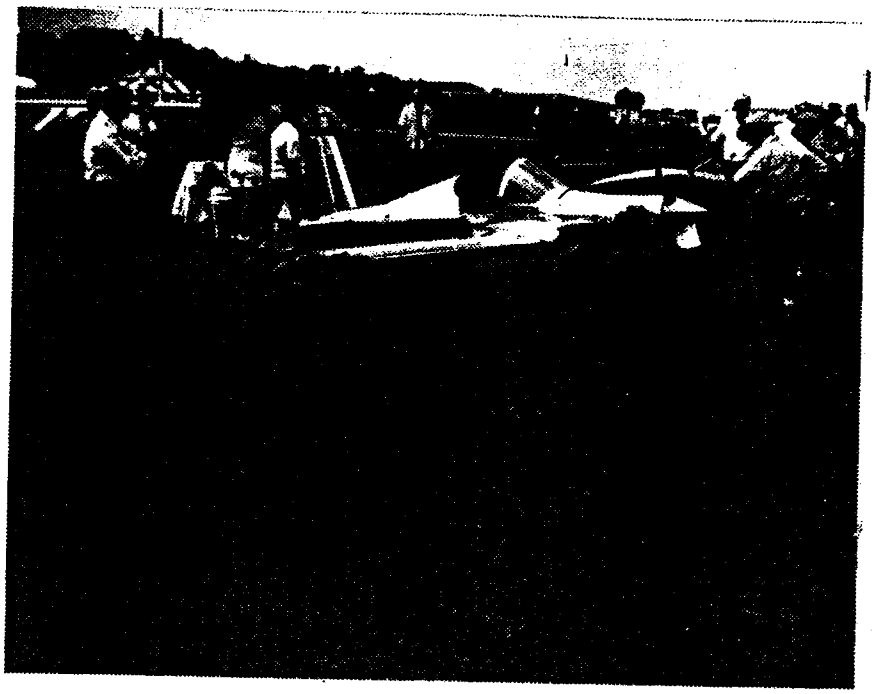
One thing I often do, on pine propellers especially, is to make a pair of discs of aircraft plywood about 1/8 inches thick and the same size around as those steel disks, (see page 42, nine lines from the bottom), which I used when I carved the hub. I glue one of these plywood disks to the front face and the other to the back face of the hub. These are put there to help prevent the tension from the propeller bolts from crushing the wood of the hub. They cannot do the job alone though, The man with the wrench must use his brains.(If he has any). He can crush any hub by leaning on the wrench hard enough! I do not use a torque wrench for this so don't ask me how many pounds I pull.I use a wrench about 7 or 8 inches long and my educated wrist. I have never had a hub loosen. I check the nuts after the first hour flight, but again, I am careful not to over tighten. I use 3/8 inch bolts in my VW prop hub and elastic stop nuts. They are much easier to check than castle nuts so the job is more likely to get done.

Mounting, testing and adjusting propellers.

When I mount a propeller on the hub of an engine I also track it at the same time. What do I mean by the term "track"? I mean that after the propeller is mounted and all the bolts are tightened the proper amount that when the propeller is turning both ,(or all) the blades will run in the same track, rather than be out of line with each other. I put the propeller on and tighten the bolts so they are just snug, and turn the propeller so that one of the blades points straight down. Then I get a box or a chunk of wood that is just a little taller than the distance from the tip of the blade to the ground and set it behind the propeller and put a stick or a little piece of board on top of it and move it so that the end of it just touches the back edge of the blade. Then I turn the propeller so that the other blade or blades also pass this point, and note how much closer or farther from it they pass. Then I tighten the bolts in the hub a little at a time and in such amounts that when I have all the bolts drawn up to the proper tension, the tips of the prop are all passing the point at the same distance from it. Having the propeller tracking properly contributes toward the smooth operation of the propeller. We were told some years ago at a forum, that occasionally one finds a propeller which in spite of its being perfectly balanced staticly and properly tracked, will still vibrate badly in spite of all efforts to remedy it. Many of these are incurable. Even new metal ones factory made, can be like this and refuse to respond even though shortened and re-pitched and rebalanced. They just have to be discarded. Here is a place where a dynamic balancer like they use to balance car tires would be handy to have. They are rather expensive to buy but it seems to me that a man who knew his electronics could build one.

According to my experience it seems that light pine propellers run smoother than heavy propellers do. The pine propellers that I have made for "Die Fledermaus" weigh about three pounds apiece.

One thing to watch on wood propellers is that when the plane is parked the propeller should be left in the horizontal position rather than in the vertical one. This is because when in the vertical position the moisture which is always present in the wood tends to gravitate to the lower blade and tends to unbalance the propeller.



This little plane with its "Sawed in Two" VW engine and its four blade propeller should be proof enough that a multi-blade propeller can give good performance on a low powered plane if it has been well "tailored" to the plane and to the engine also. Besides this it can also give more ground clearance and a lower noise level. It may require more careful testing and tuning though to do it.

How I Make Wood Propellers

Experience gained while making propellers for "Die Fledermaus"

I started construction on "Die Fledermaus" in the fall of 1964, but because of the press of farm work and of other duties it was not until Christmas time 1971 that I had enough sticks put together for it to move under its own power. Even then it was without wings and tail surfaces, and had only a makeshift landing gear. I was not deterred by these small obstacles,-----so in an effort to find out all I could about the potentialities of the 36 HP VW engine which I had chosen for a power-plant, I spent quite a few hours running back and forth with it out in the field. The neighbors never said anything to me about it, but their womenfolk had discussed it at the Homemakers Club, and had made the remark within the hearing of my sister that it would never fly. Meanwhile wings were completed and everything was covered. In the summer of 1973 a little skirmish was hadwith an accidental lift off, after which some "adjustments" were made, and a more serious attitude assumed.

At Oshkosh 1974 I took measurements from a new wood propeller which I saw on a T-18. I did not have the instruments to do a really accurate job of it, but what I did have allowed me a hint as to the distribution of the pitch along the diameter of the blade, and somewhat better data on the matters of bladedwidth and thickness. When I got back home I set about to design a scaled down, pitched down, revved up copy to fit my "Fledermaus" and its 36 HP VW engine. I figured that this prop was the latest one to have been designed by a real operating professional propeller designer at the whole Fly-In. Most of the rest of the wood props there had been designed 30 or 40 years before when the planes that they origonally made for were being produced. I applied to the best of my ability, the principles expounded in Lu Sunderland's article in SPORT AVIATION, Nov. 1973, pages 15-23, as far as diameter, pitch distribution, and airfoil shape was concerned. I made it a little oversize because if it were found to be too large it would be quite a simple matter to cut it off, but if it proved to be too small, it would be rather difficult to make it larger. I divided the blade into six stations and made the tangent of the station next to the hub .60 and of the other stations .48, .38, .30, .24 and .20.

This means that the pitch at the station next to the hub would be 60 percent of the circumference of the propeller at that point,

How I Make Wood Propellers

Experience gained while making propellers for "Die Fledermaus"

and the pitch at the tip of the blade would be 20% of the circumference at the tip of the blade. The pitches at the stations in between were proportioned much like that aforementioned SPORT AVIATION article said they were on the Piper Cherokee. I always use tangents for measuring angles on a propeller instead of degrees. They are easier to work with and more accurate than using degrees and minutes. One does not need a protractor to measure them, or to draw them, and no degree tables either. They, in this case are simply the quotient obtained by dividing the pitch at this point on the blade by the circumference at this same point. The airfoils at the various stations were made to have a camber of about 3% so they were all double convex rather than flat on the bottom like most carvers make them. Templates were made for each of the six stations and a small level was used to insure that pitches and airfoils were the same on both blades. Maybe someone will say,"Oh! My!!, that was an awful lot of work! Couldn't it be done without going to all that bother?!!" answer to that is,"Yes,- maybe it could. I have no doubt but that there are people in this country who could carve out a useable (in emergency) propeller using nothing more than a hunting knife or a hatchet and a red hot iron rod to make the bolt holes in it, but it probably would not run so smoothly, nor perform as well as one built with better tools.

This prop, when finished, had a diameter of 53 inches and 34 inches of pitch. When first tried on the 36 HP VW it would turn only to 2500 and quickly heated the engine. I cut 1 inch from the diameter and tried it again, and cut off another, and another. At the diameter of 50 inches it turned 2800 static on the 36 Horse engine. In taxi testing, initial accelleration was not as good as withsome others, but at near takeoff speed it was considerably better than with others.

The first flight of "Die Fledermaus" was made by test pilot Vern Sanders using this propeller. My first flight in this plane was also made using this propeller. A number of flights were made using other propellers but except for takeoff, this one seemed to be the best. A new propeller was carved using the same templates at the same angles but with the stations set in closer to the center by the proportion of 50/53 but keeping the overall diameter of 50 inches. The ultimate effect of this process was that this new prop, while using the same templates, had two inches less pitch and slightly narrower blades. The airfoils and the angles at which they were set were the same. One had to look very closely to see the difference, but when I got out to the beginning of the runway and opened the throttle I could immediately tell the difference! This prop turned 2900 static, and 3050 right after starting to roll. It turned 3300 to 3400 in a climb at 80 MPH and close to 3500 straight and level compared to 3100 in a climb and 3200 straight and level for the first one.There was not the hesitation after takeoff that there had been with the first one. These two props had rather wide blades and the tips were also rather wide. They seemed to me to run more quietly in the air than the usuall propeller.

Three other propellers were flown on this 36 HP engine. On these other propellers the rear faces of the blades were flat and the pitch distribution along the diameter of the blades was more like that shown in most propeller carving plans. One of them had a diameter of 54 inches and a pitch of 30 inches and blade widths like many of the "experts" said that it should. It gave noticably greater static thrust, but no better takeoff and no better climb, though in seemed to "hang" on the prop a little more if I pulled it up alittle too steep. It was slower and much noisier in the air at cruise, making me wonder if the engine was about to go to pieces. It also whistled when throttled back in a glide for a landing. The other two performed somewhat better, but not as well as the first two mentioned.

When the larger engine, a Type III with 88 MM NPR cylenders, was installed those first two props mentioned above were used in ground testing and seemed to be too small, so a new one of 51" diameter and 40" pitch was carved and used until the weather became quite warm the next summer. This new propeller was very similar to the first two, both in the distribution of the pitch along the diameter of the blades and in the shape of the airfoils. The pitch at the station next to the hub was 40% of that at the tip, or 16". Because this engine had about 40% larger piston displacement than the first, plus a higher compression ratio and better breathing, it developed about 75% more power. As a consequense it ran with a higher oil temperature, sometimes going as high as 210-220 degrees F at the (Go to page 53 please)

Experiences while making propellers for "Die Fledermaus"

end of a climb to 1000 ft, therefore I started looking for ways to make it run cooler. Some "experts" advise increasing the pitch on that part of the propeller which passes directly in front of the engine as a remedy for this situation. So I designed and carved a new propeller quite similar to the 51 X 40 just described with the exception that this one had 24 inches of pitch at the station next to the hub instead of the 16" which the first one had. Takeoff run was extended noticeably but climb was hardly affected. It would cruise at 80 with 100 RPM less but the engine seemed to be working harder. I did not then have a manifold pressure gauge so I could not make an accurate comparison as to the amount of power being used... One thing was sure, adding pitch at this part of the propeller disc did not help oil cooling much, if any,- but it does add to the total pitch of the propeller. I reduced the diameter of this propeller a bit to allow it to turn faster at static (1½") but even this did not help performance.. I made two pitched down versions (by setting the stations in closer to the hub), but this did not help either performance or cooling.

During the following winter I made an all new aluminum cowling to replace the origonal fiberglass one, and added a full spinner. A new narrower blade propeller was also carved having a pitch next to the hub of 20", halfway between the pitches of the other two designs. The new prop, the new cowling, and the full spinner did not help the cooling of oil one bit, nor the performance either that I could detect. It only made it harder to check the oil and to remove the cowling, to check the propeller bolts, and to change the propeller, so I took that large spinner off. I installed a small Corvair oil cooler on top of the engine and that did the trick. This narrower blade prop was noisier than the the others and shortly after this, while landing at a Chapter Fly-In I let the plane bounce one too many times and knocked the tips off it.

I also made a pitched down version of that 51 X 40 prop that I first used on this engine, using the same templates as the first one but spacing them so that I obtained a diameter of 52" and a pitch of 37½". This propeller, while it did nothing special for the cooling, did seem to help takeoff a bit. It also took a few more RPM to cruise at the same speed and made more noise at static runup, but was generally satisfactory,

How I Make Wood Propellers

Experiences while making propellers for "Die Fledermaus"

The first time I flew to Tobacco City and the first time I flew to Oshkosh I used this prop. Once I climbed to 7000 ft with it and the only time I have kept the throttle wide open til it quit accellerating I was using this prop. The tachometer went to 3700 and the airspeed to 123 in level flight. One thing I did notice about it was that at cruise speed it seemed to have recurring periods of very light vibration every few seconds when the air was very smooth.

Ten more propellers than I have so far described have been flown on this plane with this engine. The best one for a long time I call my "Butter Paddle Special". This is because the tips of the blades are considerably wider than one usually expects to see. It has a pitch of 39.3" at the tip,and 16" at the hub and a diameter of 50". Between the hub and the tip the pitch increases at a slower rate than on the other propellers I had made up to this time,--more like the distribution on that old PT-19 propeller I told you about quite a few pages back. Almost as soon as I got into the air with it the first time,it seemed to be flying quieter and smoother than any I had used before. I tookoff for Oshkosh with it a few days later with about 35 lbs of baggage(camping gear, clothes, tie-down equipment etc,)and returned eight days later. With this prop it cruises at 90 MPH at 2900 RPM on 17½" of manifold pressure while burning between 2.7 to 3 gallons of leadfree premium automobile gas an hour. It is my belief that this "Butter Paddle Special" was the very best that I had used on this plane. Just recently (August 1983) another **exceeds** it at takeoff and climb and cruises at **2950** at 90 mph too.

Two other two blade props which I made after this "Butter Paddle Special", were carved from mahogany instead of from pine like the others were. They used approximately the same blade shape as the "Butter Paddle **Special**" but used the pitch distribution of the PT-19 propeller. They had the same blade angle at the tip but at the section next to the hub had a pitch of only **13½**" instead of the 16" that the others used. The line of progression was also flatter and this had the effect of reducing the effective pitch of the resulting propeller slightly. The first one performed quite well, but had an excess amount of vibration which I could not seem to balance out of it. I attributed it to

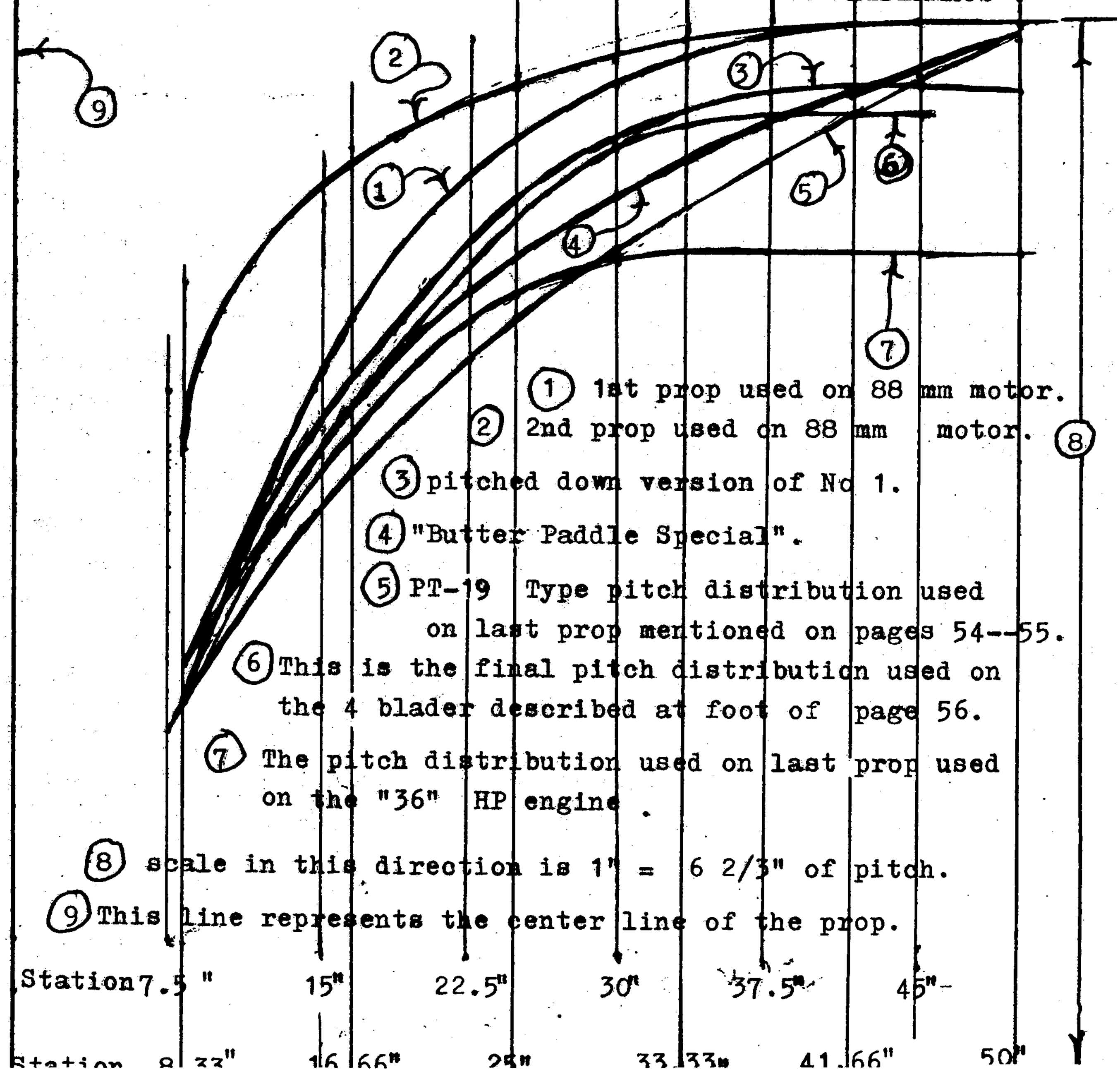
(Go to page 55)

How I make propellers.

Experiences while making propellers for "Die Fledermaus".

my carving this one without using templates. I then made a second one from the same material, but this time I made templates like I had for most of those I had made before. This one ran smoothly and performed very well but it had to turn slightly faster to give the same airspeed. It also used about ½" less manifold pressure to do it so it probably did not really take any more power. It did, however, cause the oil temperature to run a tiny bit higher, but did not seem to take any more gas even though it had to make a few more turns to the mile. Some time I want to make a prop using both the pitch distribution and the blade shape of that PT-19 propeller.

PITCH DISTRIBUTION for PROPS USED on "DIE FLEDERMAUS".

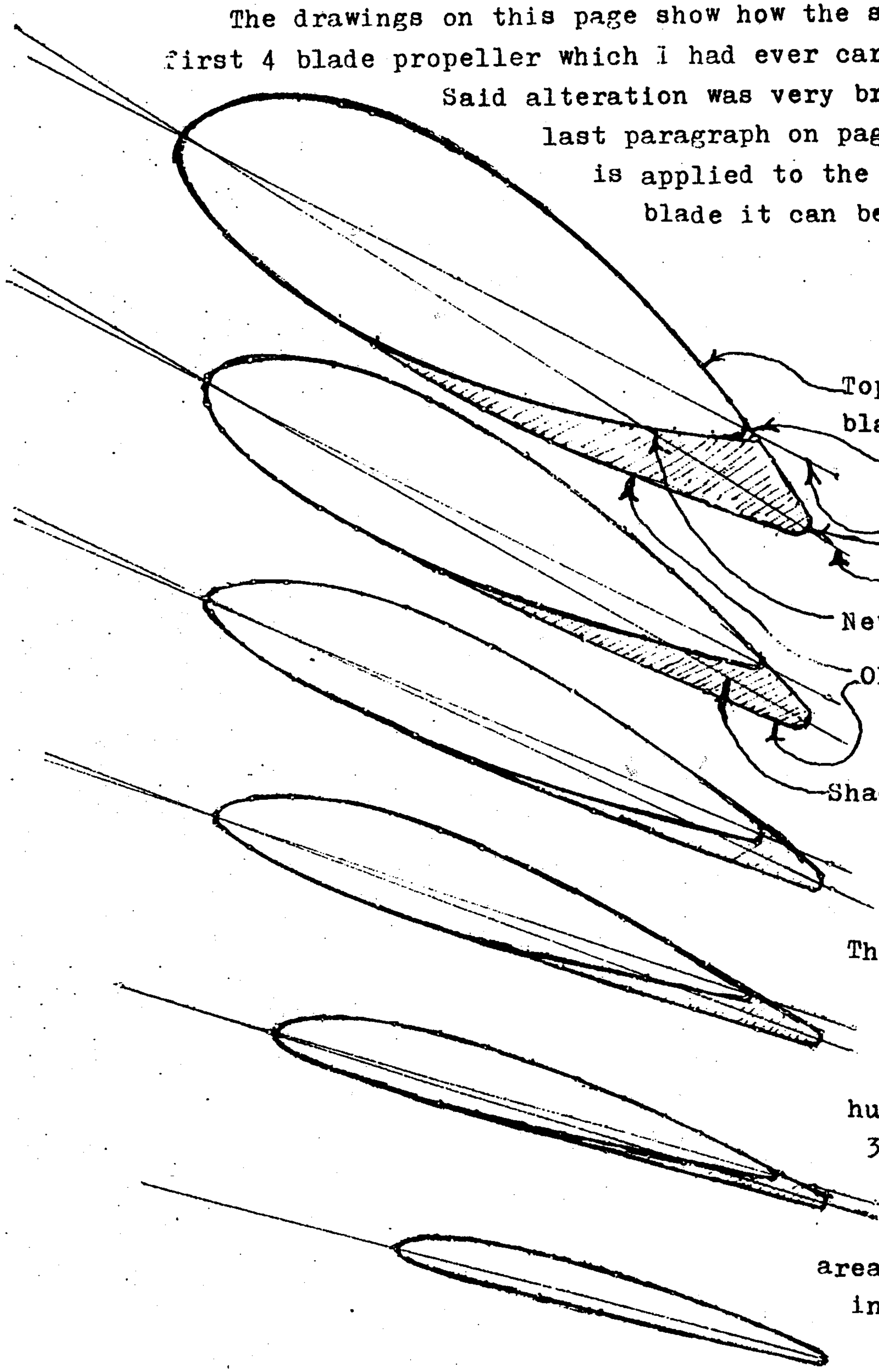


Experience while making propellers for "Die Fledermaus"

During the winter of 1979-80 I made two 4 blade propellers for "Die Fledermaus". The first one was made with a diameter of 46". It had a pitch of 38" at the tip and of 15½" next to the hub. The second one was made with the same diameter with slightly narrower blades. It had a pitch of 38" at the tip and of 20" at the station next to the hub. In June I tried taxiing both of them. The first seemed to give the most promise. The second seemed to turn too hard for the engine so I reduced the diameter by one inch and tried it again. This time accelleration was better--, but not really good. Later that day I tried flying the first one. Takeoff run was quite long and initial climb did not seem to be very good either. Operation was smooth and pretty quiet but performance all around seemed noticeably poorer than with the two bladers I had used before. I then reduced the pitch by about 2" at the tips and proportionately at all stations except the one next to the hub. All of the material was taken from the back side of the blades. The prop was hastily rebalanced and flown for approximately an hour. Performance was much improved and cruise was almost as good as with a two blader. Vibration was somewhat worse than origonally. An examination revealed that not enough care had been taken when repitching and rebalancing. This was then corrected but it was not flown again until late in the fall of 1980. When it was again tried it again it seemed to run so smoothly and quietly that a day later it was taken on a 200 mile cross country round trip. On this trip it cruised at 90 on 2900 RPM and 17½" MP. It was again removed and a couple of two bladers were tested. Late in December 1980 it was reinstalled and flown again. The only faults to be found with it were that it turned just a little too hard, and that takeoff was not quite what I might wish for.

Just before New Years Day 1981 I took it off and reduced the pitch substantially on the inner 2/3 of the blades, making the distribution of the pitch more like that of the "Butter Paddle Special" two blader. Special care was taken when sanding the blades to get out all the gouges and rasp marks, (Go to page 58 please)

The drawings on this page show how the second alteration to the first 4 blade propeller which I had ever carved was accomplished. Said alteration was very briefly described in the last paragraph on page 56. When this method is applied to the full length of the blade it can be very effective.



The first alteration on this propeller consisted moving the position o: stations closer to the hub by the proportion of 38 to 36.

The second alteration reduced both the area and the angles of the inner portion of the blade

Any reduction of eithe the pitch or of the area of a blade near the tip has a much more powerful result than a similar alteration carried out near the hub. Care must be taken because with this method, If too much pitch or area is removed it is difficult to restor and it was carefully rebalanced. When it was tried again it turned up about 50 or 75 RPM more static, and takeoff seemed to be considerably improved. 17½" MP or even 17"MP would cruise it at 90. Before one get s too excited about this though, he should remember that this was winter time and that performance of an airplane is improved in the winter. It is a case of "density altitude" working for you instead of against you as in the summer time. Operation was very smooth and quiet. Conclusions at the present time are that it was as good as the best 2bladers I had used. This prop was made of mahogany glued with T-88 epoxie glue. The laminations were ½" thick. It was just as easy to crank as a 2 blader, and was an eye catcher. I could be mistaken, but according to my experience I would say that the 4 blader should have a diameter that is 92% to 95% of that of the 2 blader, and the pitch should be 95% to 97.5% of the pitch of the 2 blader. Why should this be? I would think it is because a larger proportion of the disc of a four blader is in the slower moving part of the slipstream and this gives it a higher effective pitch than it otherwise might have. I also believe that a 4 blader requires more careful adjusting if it is to work as well as a 2 blader.

Two other 4 bladers were tried and worked quite well.

In addition to these four blade propellers I carved one five blade propeller. How did it work? Well--,it worked pretty well as far as performance goes. Takeoff was plenty good enough but it had excessive vibration just below cruising speed. At a good fast cruise it ran acceptably smooth, but just a little slower it really shook. A five blader is much harder to build than a two blader and even much harder than a 4 blader. The two blade blank needs only 4 separate pieces of wood from which to glue up the blank. The four blade blank needs 18 and the five blade blank needs 55, and they must be more accurately fitted to each other. Even then the strength of it depends much more heavily on the integrity of the glue joints. There is also much greater wastage of timber in preparing the laminations, and about twice as much glue is needed. Unless something is required to attract attention, I do not believe anyone has to have a 5 blade propeller on a VW powered airplane.

At this point you may say,"I do not yet understand this pitch thing and how and where you measure it. Another thing I can't understand is why a 54 X 36 propeller by one carver might not be comparable to a 54 X 36 propeller by another carver. And what does a man mean when he says that his prop has such and such pitch?"

If you feel this way, don't be too ashamed of yourself. Those are still valid questions even at this point in this book. I have not spoken directly to them up to this point even though I have spoken around them to quite an extent,---- so here goes--:

First off, there are several kinds of pitch. One of them is "nominal pitch". This is the figure the maker stamps on the hub of the propeller. What he means by it only he really knows(we hope). He may mean the actual geometric pitch at a certain position on the blade, - or he may mean "effective pitch", the distance the propeller is intended to progress per turn when it is used on the plane and engine for which it was designed, or he may mean neither of these. Camber and thickness of the airfoils of the blades may or may not have been taken into account when the figure was established, nor the amount of deflection,(intentional or not) taking place under load. Other factors (known or unknown) may also have entered into the picture. If enough of these factors are of such a nature that their effects are cumulative, the resulting performances from two propellers of the same nominal pitch could be very different!

On most of my props "nominal pitch" is the actual geometric pitch at the tip of the blade, measured from the chord line of the section there. At cruising speed and power, advance per turn should be nearly 7/8 of this figure for best performance. At full power straight and level it may be considerably better than this if the ship is clean.

Some years ago I talked to a man who said he had a VP with a 1600 VW motor. He said he had a propeller by a well known carver on it but was quite disappointed with the performance. He said it turned 2900 RPM static, and not a bit more in the air. I certainly do not know either how or why this is done. I do think that if such "constant speed" performance is desired, then static RPM must be set at 3500 to 3700 RPM in order to realize full power output from this engine.

The design and construction (hacking out) of wood propellers involves so many variable and unsuspected (at least to most amateur carvers) factors that few (if any) formulas can allow correctly for all of them.

How I Make Wood Propellers

I kinda fear that after some people have seen those "pitchers" of that five blade propeller, they, or at least some of them, are going to get all fired up and will want to know a lot more about it. Therefore to forstall a lot of letters inquiring about it, and to head off a lot of well meant speculation concerning what effects such a contrivance might have on the performance of an aircraft, easpecially a VW powered, or similar craft, I will here and now, disclose the information which I have obtained as a result of my experiments with four and five blade propellers on "Die Fledermaus".

I will start by saying to you who have not seen "Die Fledermaus" that it is just about the size of a Taylor Monplane or a Taylor Titch, But it is not nearly so smoothly done as either of them. It is somewhat larger than the Sonerai-I, the KR-1, or the Corby Starlet. The most oustanding difference is that it has a large wide fuselage with an ample cockpit designed to accommodate a fully grown fully clothed man(---well---,ll most of them,any way), instead of the tiny little holes that many little planes have. It was made that way on purpose because I had read that there was no advantage to be had by making the fuselage narrower than the engine, so I made it 30" wide. This plane cruises nicely at 90 MPH (checked lotsa times by the section line and on longer flights too), on 2900 RPM and 18" of manifold presure. At, about as near as I can figure out, 50% power.

As I said some pages earlier, I have flown this crude little ship,(by current standards), 516 times with 21 different propellers, (no two exactly the same), all of which I carved myself. Seventeen of them were two bladers, three of them were four bladers, and one was a five blader. Besides recording these flights in my three log books, I also recorded the various details of the flight,(the time of day, the temperature, the duration of the flight in terms of tachometer hours,the amount of gasoline it took to refill the tank(in lbs the runways I used, how the engine ran, and how the plane seemed to get off and fly, in a larger notebook, or more accurately, in series of them. When I tried a new propeller I recorded the specifications of it in a book together with my impressions of its performance,

(Go to page 60 please)

and whatever alteration I made to that particular propeller and what the results of those alterations seemed to be. These things I say not to brag, but to show that this account is not based on some hazy, vague ,long gone memories, theoretical surmising, or imagineering, but on actual experience. So much for introduction.

People have some times become very excited upon seeing a four blade or a five blade propeller on my ship and want to know,"How does it work?" or"How does it perform," When I answer, "Not just an awful lot different from a two blader," They seem let down. Some cannot believe that such a small diameter propeller could possibly give any performance,not to mention perhaps doing better than a two blader. They still believe the"experts"who used to say,"The bigger the propeller you can turn the better." Or the old old propeller carver who said to me,"The only reason some people say they get such good performance from a 4 blader is because they had such a damned poor two blader on before." We, long ago, had"authorities" who told us that we couldnt get any performance from a VW engine because"they turn too fast ", or "They must be geared down,if they are to achieve any efficiecy at all." What about the little plane we have seen at Oshkosh a couple of times now that does pretty well on 1/2 a VW and a four blade prop?

My experience is that a multiblade propeller can give good results or almost as good results as many two bladers do and take up less space while doing it. Being of smaller diameter, they may not need such a tall landing gear thereby reducing the resistance of it slightly and lowering the C.G. of the plane when on the ground,thereby improving the stability of that landing gear slightly. They can turn faster before the tips of the blades exceed the 850 ft per sec limit of the wood propeller. The 46 in four bladers that I tried could have gone 4,100 before they would have gone beyond 850 fps. Because the tips go slower the propeller can run quieter than a two blader. I never heard from the ground any of my propellers fly because I always was the pilot but when I arrived at a chapter fly-in with a four blader last summer the other chapter members remarked about how quiet my four blade propeller was.

How I Make Wood Propellers

One little "How to-" propeller carving book makes the statement that the best propeller efficiency is obtained when the tip of the propeller blade travels 3.93 times as far to the turn as the plane does. Not stated though is this: Is the peak of efficiency thus obtained very sharp??-- or is it not a very broad general one, hardly detected in actual practice?? A Sonerai going 120 Mph at 3200RPM could achieve this with a two blader. "Die Fledermaus" would have to go 107 MPH with a 4 blader turning at 3200 to do it. This of course is only theory. In actual practice there may be no detectable gain. A multiblade propeller is, in my opinion is no more opaque while operating than a 2 blader and contrary to the fears of some very little harder to prop.

Now-, looking at the reverse side of the picture,--what are the disadvantages of the multi blade propeller? Well-ll--, first off-, it takes more wood to build. But this may not really be the truth. There probably is only a little more wood in a four blade propeller than in a two blader, but there is more wood wasted during the making of a four or five blader because the sizes that the wood comes in does not fit the needs of the multiblade prop as well, consequently more of it winds up as chips and shavings or sawdust. More glue is needed because one must use more laminations, and therefore more glue joints. The two blade VW prop as I make them needs only four separate pieces of wood, the four blader 18, and the five blader 55 to do a good job! The laminations of a two blade prop do not have to be all the same thickness, but those of a multi blader probably all ought to be the same thickness. In addition to this, the laminations of the two blader need not be square on either end, twelve of the laminations of the 4 blader must be square on one end, while for the 5 blader each one of the 55 separate pieces must be perfectly shaped on one end! (as shown in the plan in the back of this book). When one glues up a 4 or a 5 blader he must have a good perfecly flat surface on which to do it, rather than just a good straight plank or timber, as with a two blader. Carving a multiblade propeller is not more difficult than a two blader though, because each of the blades is smaller and they are really no more difficult to balance because one does not have the problem of having them balance horizontaly and not vertically like sometimes happens with a two blader.

How I Make Wood Propellers

How do they work? Well--, I think they work as well or nearly as well as two bladers do. They can have as good or very nearly as good takeoff as the two blader does. At least mine seemed to. Not right away, but after I had adjusted the pitch and the pitch distribution from what I thought it should be , to what it should have been. In contrast to a two blader with a diameter of 50" and a pitch of 39" one four blader used a diameter of 46" and a pitch of 36". another four blader used a diameter of 45" and a pitch of 37.5". Both of these four bladers seemed to climb up just as well as my best two blader after the speed got up to 80 or 90 MPH where the plane climbs best. I flew the second 4 blader one day in the winter when it would climb a little on 16½" of manifold pressure. No, I don't remember it as being a particularly sunny day either. I did notice that these props seem to give the slipstream a tiny bit more twist than the two bladers do, or that's what I thought they did. Anyway they seemed to require a small amount of rudder pressure to keep them going straight ahead at cruise, but when a little more power was added it wasn't needed. There did not seem to be so much of a drumming effect from the impulses from the propeller against the windshield with these props as with the two bladers but maybe this was only my imagination.

A third 4 blade prop was made with different blade widths and a different pitch distribution, but while it performed well enough, it it seemed to be more noisy at some power settings. perhaps the blades were too thin and the blades were fluttering, I don't know, consequently I haven't flown it much. I may sometime fiberglass the blades and try it again, but I don't know when.

Now let's talk about that five blader.

I suppose to some the most difficult question is,"How did you get those five blades equally spaced on that prop?" Well let me assure you that that was the least of my troubles, certainly much much less trouble than running this darned typewriter. No, I did not use the dividing head from a milling machine, nor the rotary table from a large drill press, nor a big protractor, nor did I fold a sheet of paper just right and cut out a perfect five pointed star with a single snip of the scissors, nor divide a circle into five equal parts with a compass like we learned in geometry class in high school. (Go to page 63, please)

How I Make Wood Propellers

I simply drew a circle 46" in diameter on the table on which I was going to set up my gluing jig. Then I multiplied the diameter of this circle by .5878 and this gave the length of the side of the pentagon that could be inscribed in that circle. Very simple isn't it?

Well--now lets--seeee-, I spent a lot of time a few pages back trying to impress you with how scientific I had been with all of this wood butchering and how I had kept such good records of what I had done,- Hmmmmm---,M-MMaybe what I should do is just to read from those records.-

Report of operation of propeller 46 X 37.4 5B, 6-26-81 .

This prop finished August 20, 1981. Building it was quite a lot of work, especially preparing the blank for it. It was made with 11 layers of laminations each.215 inches thick. Preparing and fitting these laminations a very big job. Gluing took three hours, using Elmer's Water Proof Glue. It took about ten dollars worth,(the quart sized cans). I think now that it might have been better to have used epoxy glue and have glued only half of the laminations at one time. The laminations were each tacked in place using ½" smooth wire nails at the edges to keep them from shifting as the clamps were tightened. These laminations were 3¼" wide, just barely wide enough to make the hub 5" in diameter.

Carving after the block was glued was not a difficult task. Not much wood had to be removed because of the small size of each blade. Templates should have been used sooner because by the time I had started to use them I had already gone too far on some Of the blades, so I had to make them thinner than I had intended. This was not so very serious though because they still seem to be amply stiff. Balancing did not seem to be difficult either, however a good dynamic balancer would be nice so that one could finish the job with prop right on the engine.

When the propeller was mounted on the engine and run up it went to 2900 or almost. It made a rushing sound instead of the normal sound of a two blader. It was first flown without any varnish on it. Takeoff was almost as good as with the Butter Paddle Special. Climb out was most as good at 3400 and 90 indicated. Operation was quiet and smooth. Although it would fly at 93 mph at 2900 it would not seem to hold altitude at that figure hands off, due I believe to the(Go to Page 64)

fact that this prop weighs 4 lb instead ofthe 3 lb the Butter Paddle Special weighs. This prop was flown for .73 tachours on this first flight. It was also noted that the oil temperature ran a bit higher too. Temperature in the air was 65 degrees F.

The prop was then removed from the plane and sanded quite well and filled with silex wood filler and given two coats of varnish. It was rebalanced by adding another coat of varnish to several of the blades. The prop was flown again at 95 MPH at 3150 RPM for approximately 1.34 tachours on August 22. At this speed the engine ran more smoothly than it had at 2900. Also it seemed to be more in harmony with itself, but it did run hotter on oil temperature. With the outside temperature of 70 F oil went to 200 F. I had put Micro-TFE in the oil after returing from Oshkosh and I must yet be convinced that it does anything good for your engine. Air during this flight was very smooth and a uniform temperature of 70 F. When I refilled the the tank after landing the amount of fuel used per tachour and clockhour seemed not to be significantly greater than before, and operation had seemed to be quieter than with other props. I was quite well pleased so far with the results of my tests. I do feel that if I were making another I might make the blades a little narrower,(about ¼") at the hub and maybe that much wider at the tips of the blades, or possibly just increasing the tangent at the tips to .27 instead of .265. Another way to do it would be to move the tip template to the 46" diameter point from the 45" diameter point. This would increase the pitch by .83 inches.

Additional notes and comments on 5 blade prop No. 46x37.4 5B

During my test flying of this prop it still seemed to have a little more vibration at some speeds than I thought it should have. When running on the ground the spinner seemed to wobble more than it should and the front plate did not seem to set quite where it was intended to set when I carved the hub. I put the 3/4" to½" bushing back in the center of the hub and put the aluminum front plate on with a ½" bolt through the center hole of the plate into the centering bushing in the prop and found that the bolts that held the prop to the engine would only go part of the way through the hub, so I took the prop to the drill press and drilled through my steel prop drilling template and thereby shifted them slightly on the front face of the hub so that the bolts would now go through quite easily(push fit) while the front plate was centered with a piece of ½" tubing. This, it was hoped, would make the spinner run more nearly true.

Following this the back surfaces of the blades were all sanded quite thoroughly lengthwise and crosswise to remove all gouges and undercuts and varnished again. Next the front side was given the same treatment, but much less effort was needed to bring these to the desired condition. I then checked the balance with the aluminum front plate in place and the bolts in their holes and balance was restored by adding varnish to the lighter blades. After the varnish had dried the propeller was again installed on the engine using a piece of ½" tubing to center the front plate and carefully tracking the blades. Wet drizzly weather prevented flying that day.

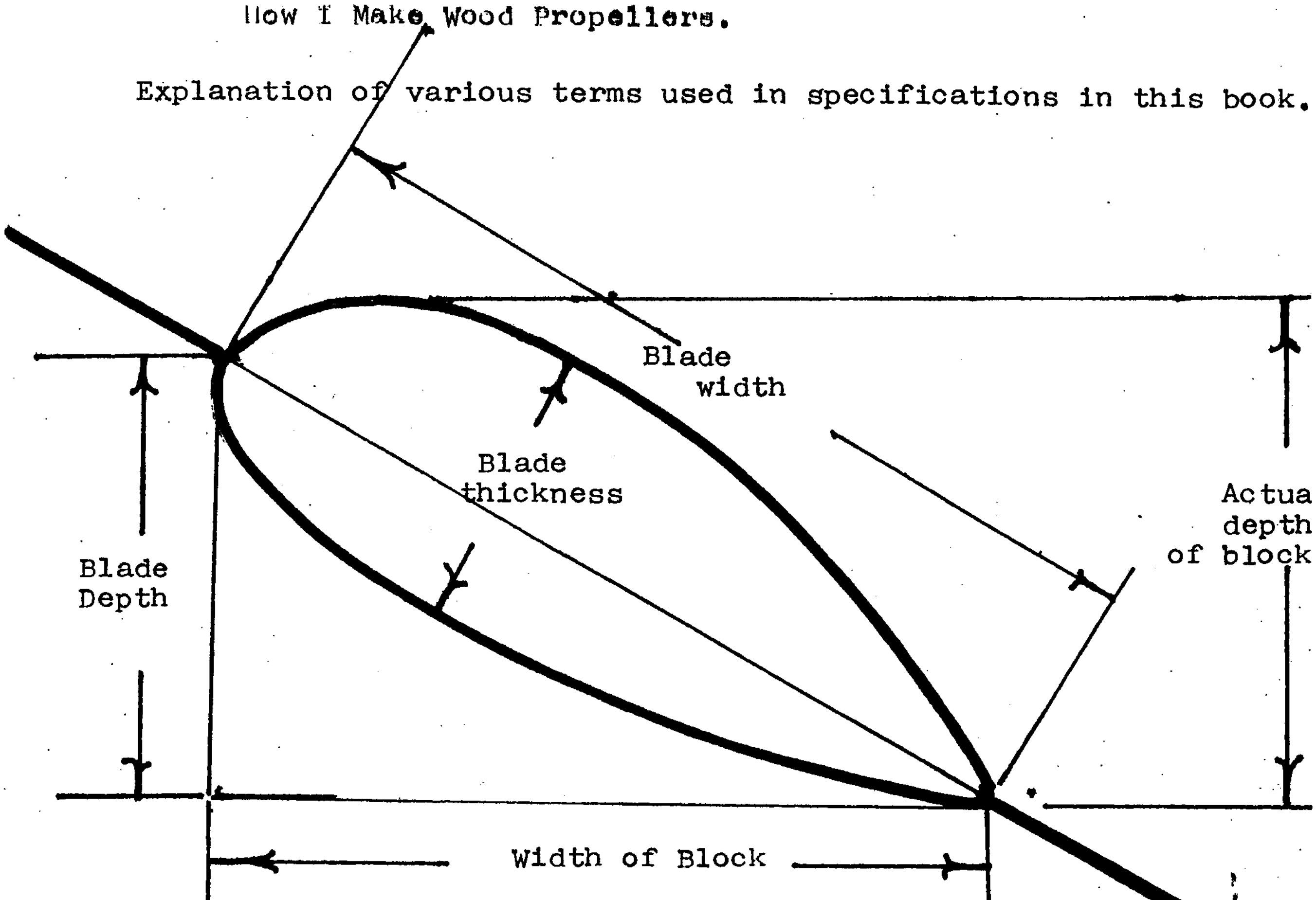
I went up the afternoon of August 29 after 5 O'clock to see how this prop worked after the recent work on it and was very dissapointed with the amount of vibration, especially between 2400 and 2850. At 3000 it ran quite smoothly. I did not stay up very long. I came back home and took the prop off and turned it 180 degrees on the hub and put a couple of washers on a certain hub bolt and went up again. I flew to Winona and talked briefly with Mike who was putting the planes back into the hangar for the night. After a bit I cranked up, took off and came home. Take off was good, climb was good, but a little more manifold pressure was needed at cruise with the 5 blader than with the EPS and I believe gas consumption was also a little bit more. I think what I need is a dynamic balancer with a strobe on it so that I can find the right place to put the counter weight and how much to put on.

August 30 I put the Butter Paddle Special 50 X 39.3 back on and took it up. I found it to run very smoothly and quietly. It is really the very best I have tried so far and I think it gives the best gas economy also. I am thinking of trying a shorter two blader, say like a 48" or a 46". These would have to have wider blades, of course.

Well-----, this is the end of the origonal part of the book, except for the summary, afterthoughts, and the conclusion. Only a few copies were printed, --by Xerox, of course. I did all the text, the typing, the proof reading , the sketches . The pictures were snapped by me also. So I must plead guilty. I have since made several revisions.

How I Make Wood Propellers.

Explanation of various terms used in specifications in this book.



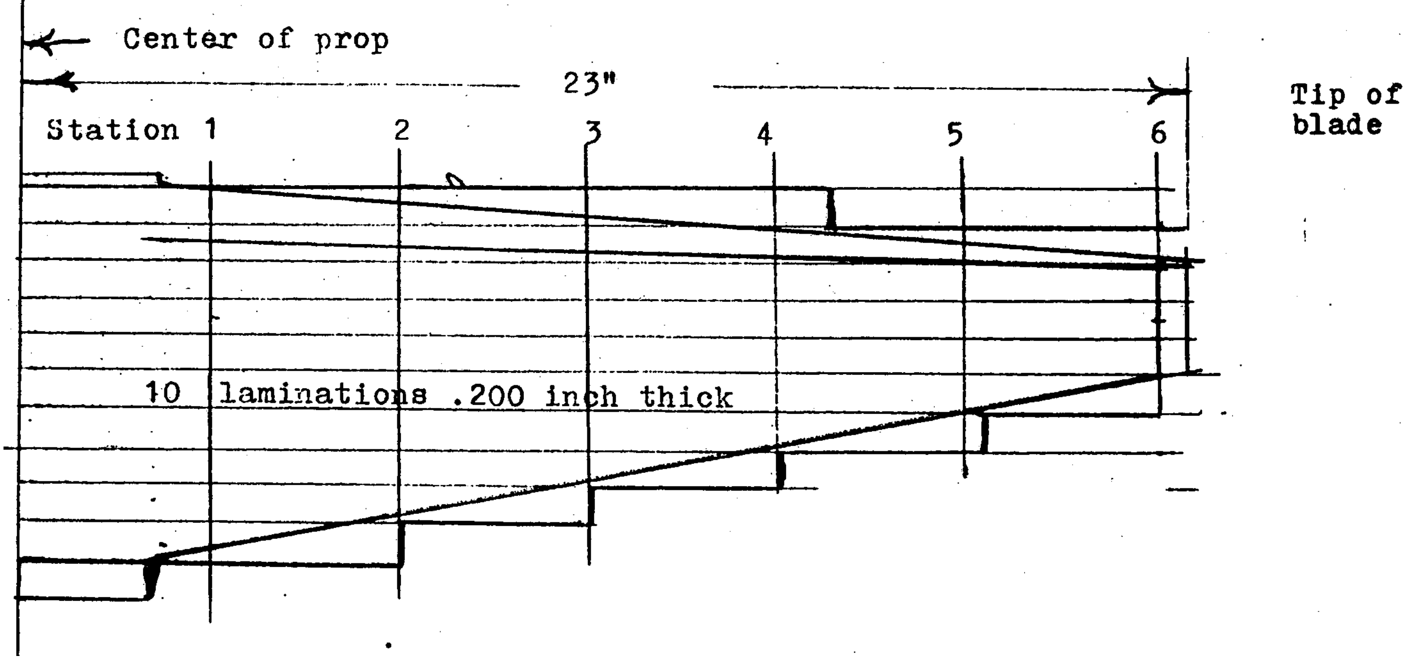
NOTE, The term "Tangent" equals Blade Depth divided by Width of block--and conversely--; Block Width times Tangent equals Blade Depth.

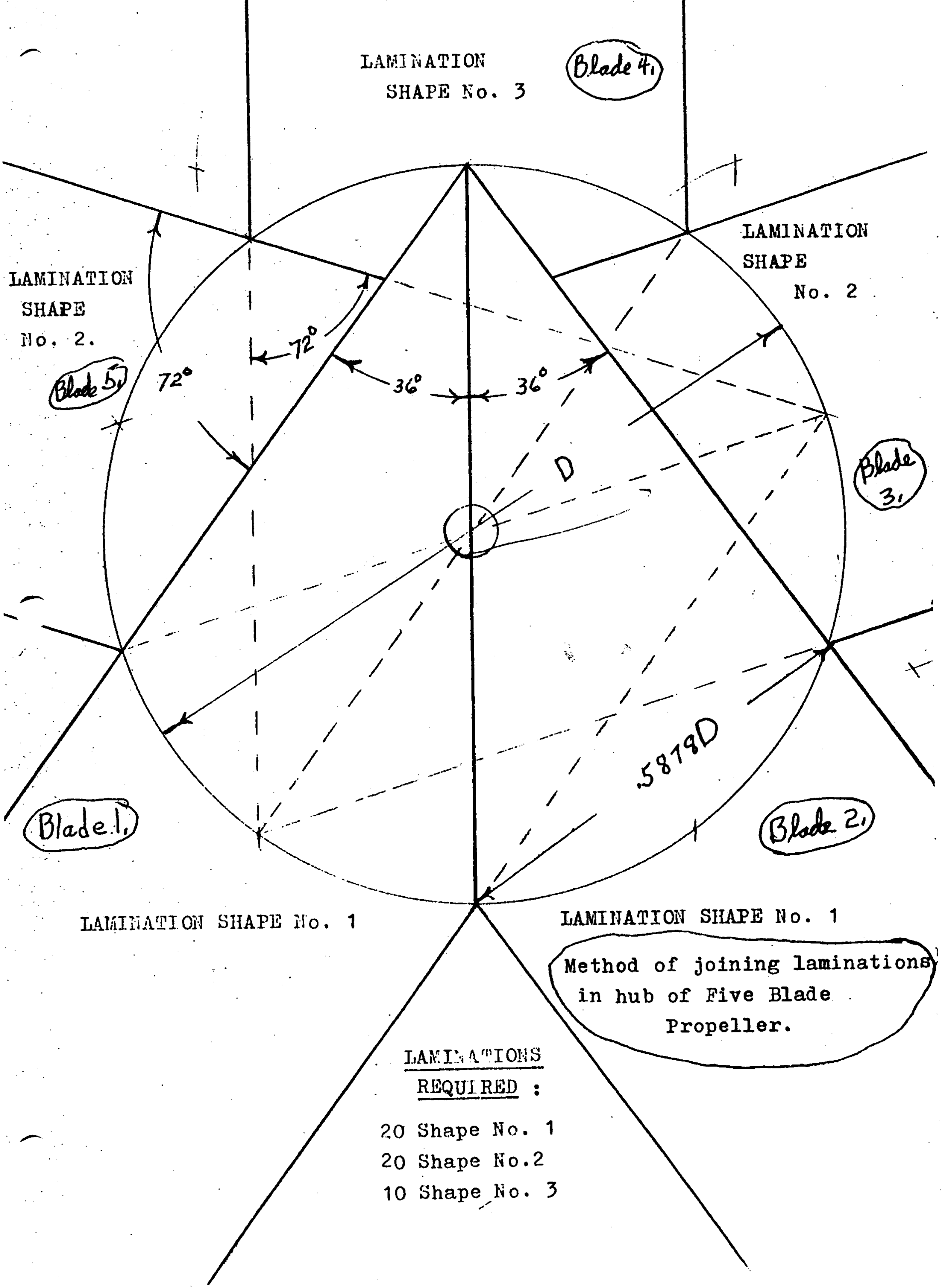
Further NOTE, In many of the propeller specifications given in this book the dimension here called Blade Depth is called "Block Depth" but in those cases the "Actual" depth of the block is greater just as as it is here.

4-8-81 BPS-5-B 46 X 37.4

Diameter	7.5	15	22.5	30	37.5	45
pitch	13.7	23.6	29.6	33.4	35.9	37.4
% of Pitch	36.8	62.9	79.2	89.4	96	100%
Circumf	23.5	47	70.5	94	117.5	141
Tangent	.587	.502	.42	.355	.305	.265
Blank Depth	1.65	1.43	1.21	.99	.77	.55
Blank Width	2.80	2.86	2.88	2.79	2.53	2.08
Blade Width	3.25	3.19	3.14	2.96	2.65	2.15

NOTICE !!! This and the next two pages contain all of the dimensions and drawings necessary to build a "Five Blader" If you decide to try one my advice ~~is~~ Be very, very carefull! I do NOT have unlimited confidence in the hub! I NEVER let it go faster than 3450 rpm, at any time and I can't say for sure that it was safe even then. I tell about it on pages 59, 60, 61, 62, 63, 64, and 65.



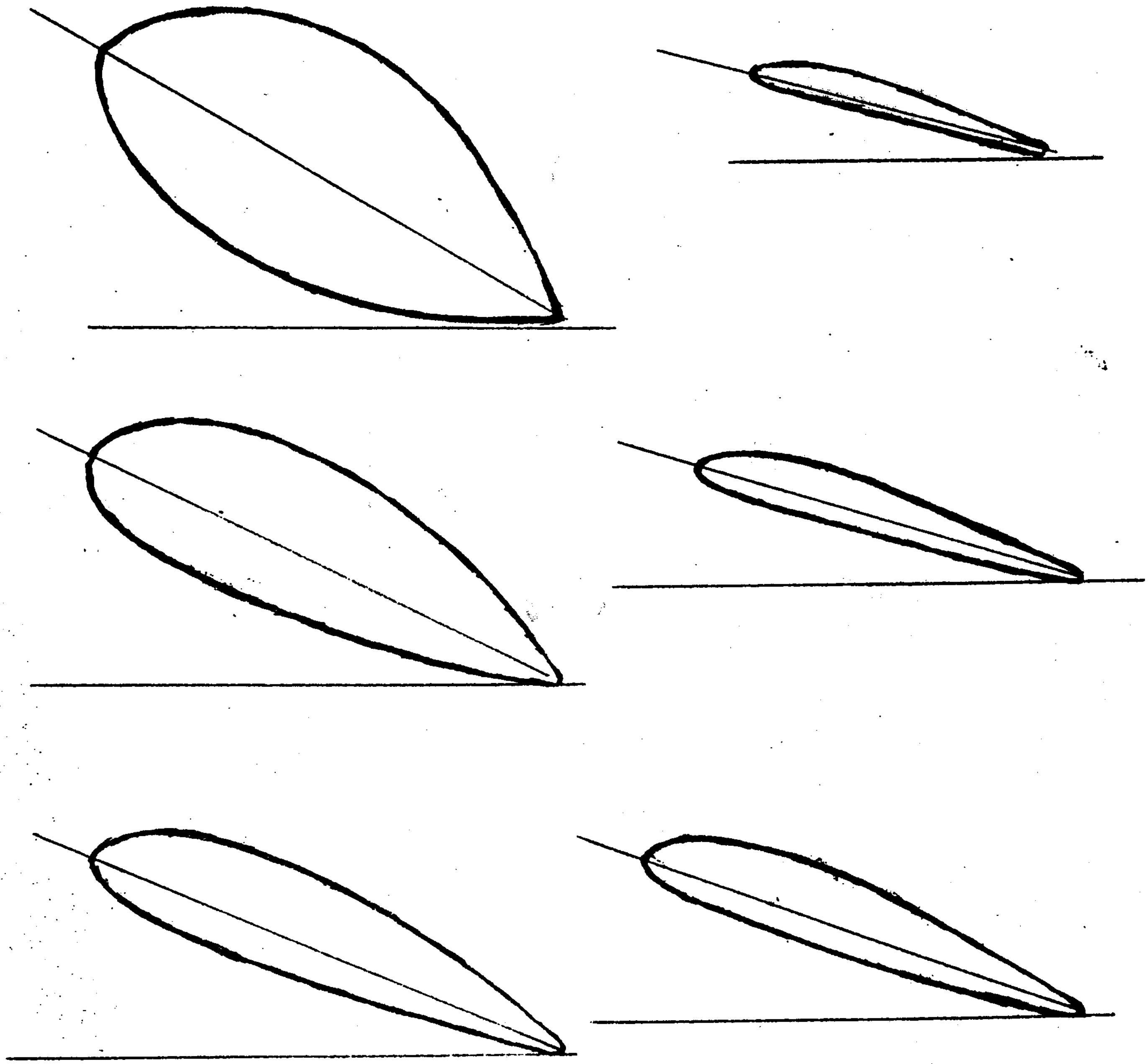


Method of joining laminations in hub of Five Blade Propeller.

How I make propellers.

Airfoils and Angles for propeller No.

4-8-81, BPS-5-B,46 X 37.4



These are the airfoils and angles for this 5 blade propeller described in these last few pages. The actual thickness of the airfoils are somewhat less than these drawings show them to be. See story on pages 59, 60, 61, 62, 63, 64, & 65.

How 1 make propellers.

Propeller Design No. PKS-1 was designed and carved in the spring Of 1980. diameter and pitch were decided upon after using the formula found in the article written by Lu Sunderland in Nov. 1973 SPORT AVIATION pages 15 thru 23. Several assumptions were made at this time in order to make the use of this , or any other formula possible. These assumptions were:

1. That the Corvair engine as converted by Mr. Pietenpol would develop 85 HP at 3200 RPM.

2. That with this amount of power this particular Aircamper would fly 85 MPH.

This formula plus specification quoted for propellers tried earlier on this engine led me to believe that a propeller having a diameter of 60 inches and a pitch of 30 inches would do the job. To be sure, 1 would make it a couple inches longer than that. I could cut it off if it should prove to be too large. If it were too small that would be much more difficult to fix.

Here are the specifications which I developed:

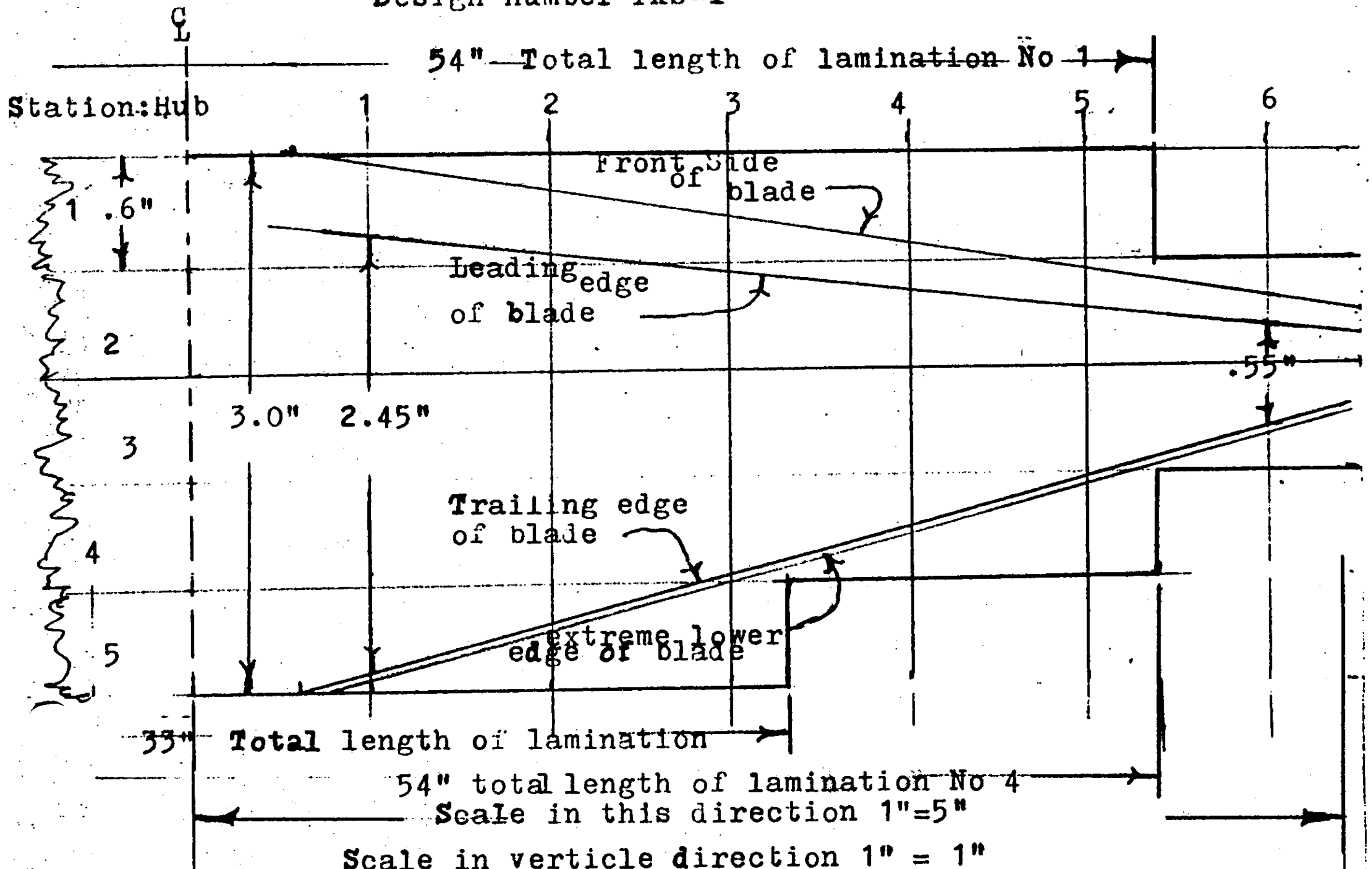
Station	1	2	3	4	5	6	
Radius	5	10	15	20	25	30	inches
Diameter	10	20	30	40	50	60	"
Circumference	31.4	62.8	94.2	125.6	157	188.4	"
Pitch	15.5	24	27.6	29.3	30	30	"
Tangent	.49	.384	.294	.234	.19	.16	
Width of Block	5.0	5.4	5.75	5.60	4.88	3.45	inches
Depth of Block (width X tangent)	2.45	2.01	1.69	1.31	.93	.55	"
Width of Blade	5.56	5.9	5.98	5.76	5.00	3.51	"

I then drew a side view of one of the blades,(from the center to the tip) showing the individual laminations, the positions of each of the stations, the leading and trailing edges,and the most forward points on the airfoils. This drawing is made to a scale of 1"=1" as far as the vertical dimension is concerned,but to a scale of 1"=5" as far as the horizontal dimension (diameter) is concerned. The use of the two different scales is necessary in order to get the whole drawing on the page, and is totally adequate as far as getting all of the necessary information on it goes.

How 1 make propellers.

Plan for propeller for Corvair powered Pietenpol

Design number PKS-I



NOTES:

There are five laminations each .6 of an inch thick, each 6" wide.
One lamination (No. 5) is 33" long.
Two laminations (No. 1 and No. 4) are 54" long .
Two laminations (No. 2 and No. 3) are 64 long.
Lamination No. 1 is on the front side of the propeller.
Lamination No. 5 is on the back side of the propeller.
This propeller was made of mahogany
The stations on this propeller are all 5 inches apart.
Rotation of the Corvair as converted by Mr. Pietenpol is to the left when viewed by the pilot from the cockpit.
This propeller should be made to the diameter of 64 inches and then after trying it should be cut off until it turns the proper RPM.
Spacing all stations 5 3/8 inches apart instead of 5 inches will increase the pitch of the resulting propeller 2 inches.

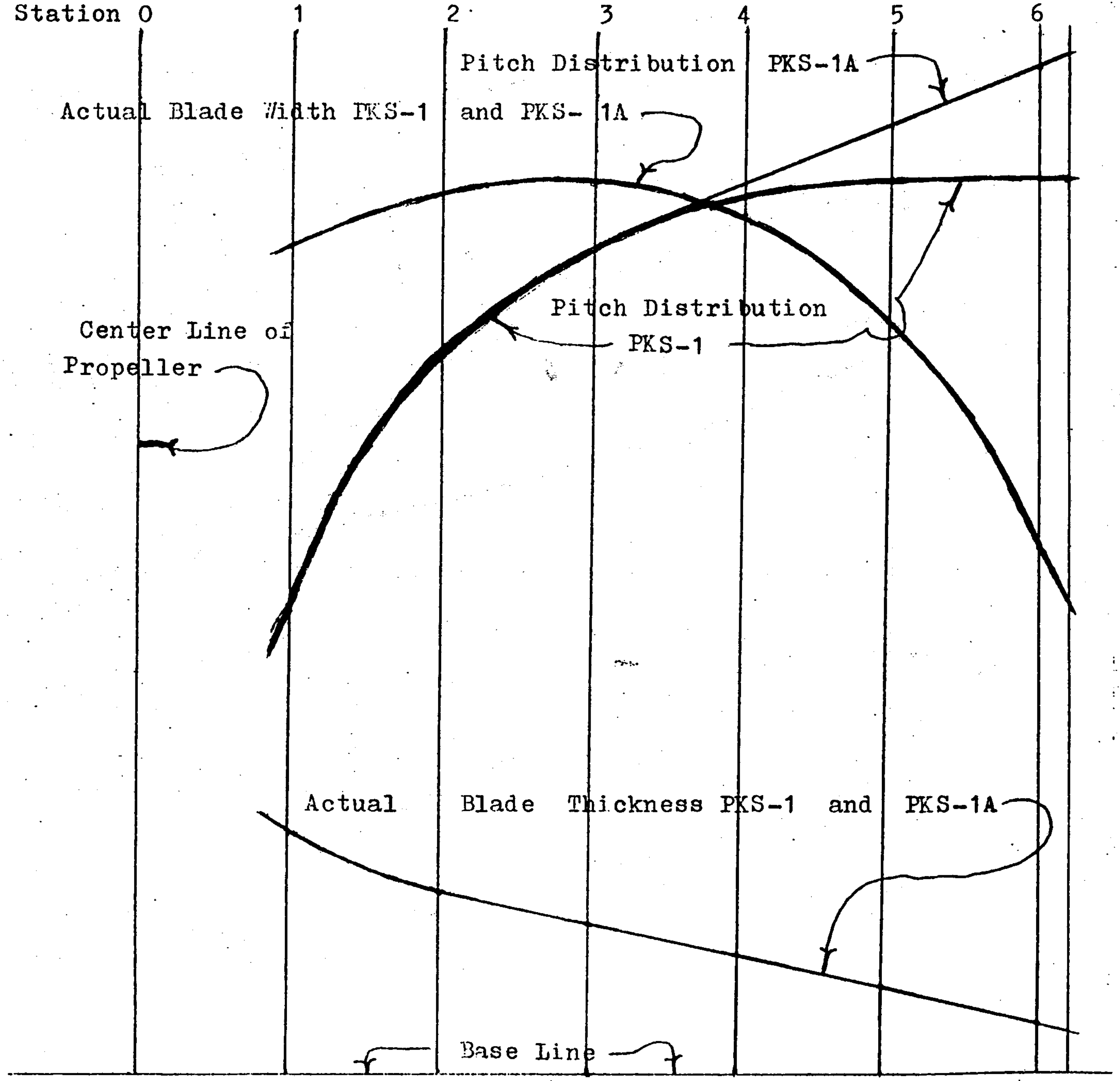
How I make propellers.

PKS-1 , PKS-1A propeller plan Page 2.

This would then make it 64 X 32. If it then turned too hard 1/2 inch could be removed from each tip for each 100 RPM it turned too slowly. If one felt that the 30 inch pitch as origonally designed is too great, the templates can be respaced 3/8 of an inch closer together and the blades recarved,(just a small amount of wood needs to be removed), and there is the same prop with a pitch of 28 inches.

The graph below depicts graphically; Blade Width, Blade Thickness, and the distribution of the pitch along the diameter of the blade.

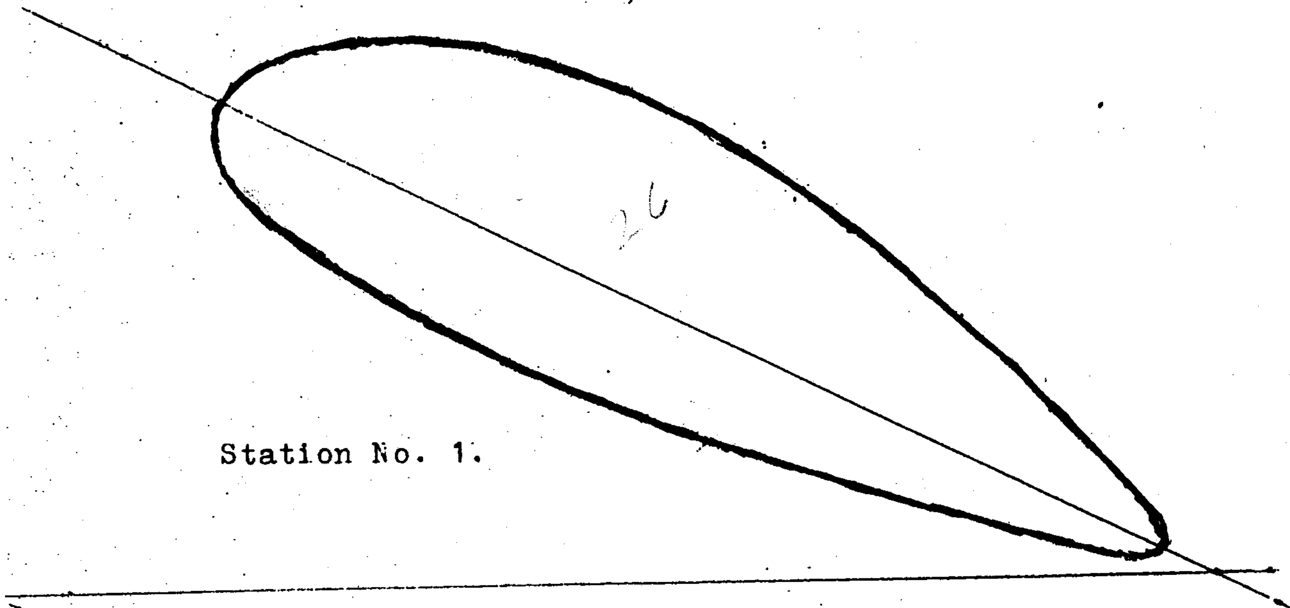
Station 0 1 2 3 4 5 6



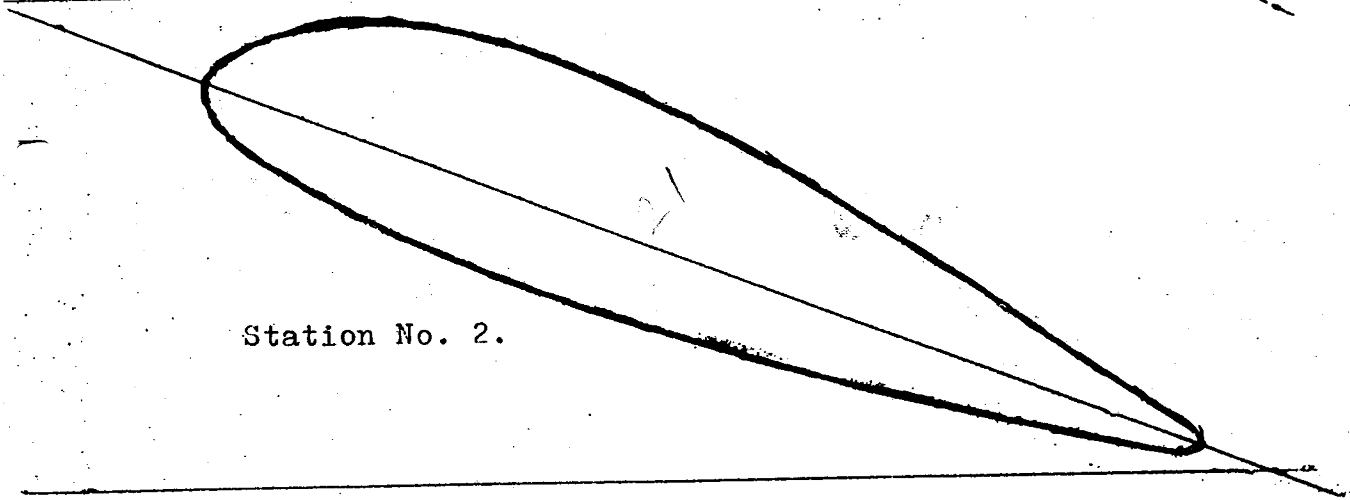
How i make propellers.

Airfoils and angles for propeller for Corvair powered Aircamper.

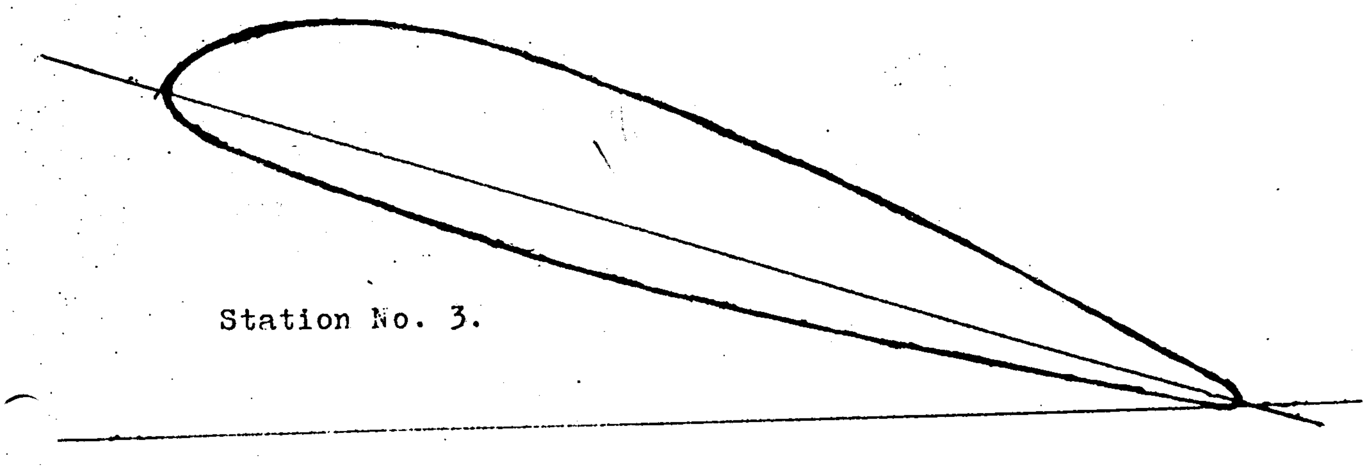
Design No. PKS-1 and PKS-1A



Station No. 1.



Station No. 2.

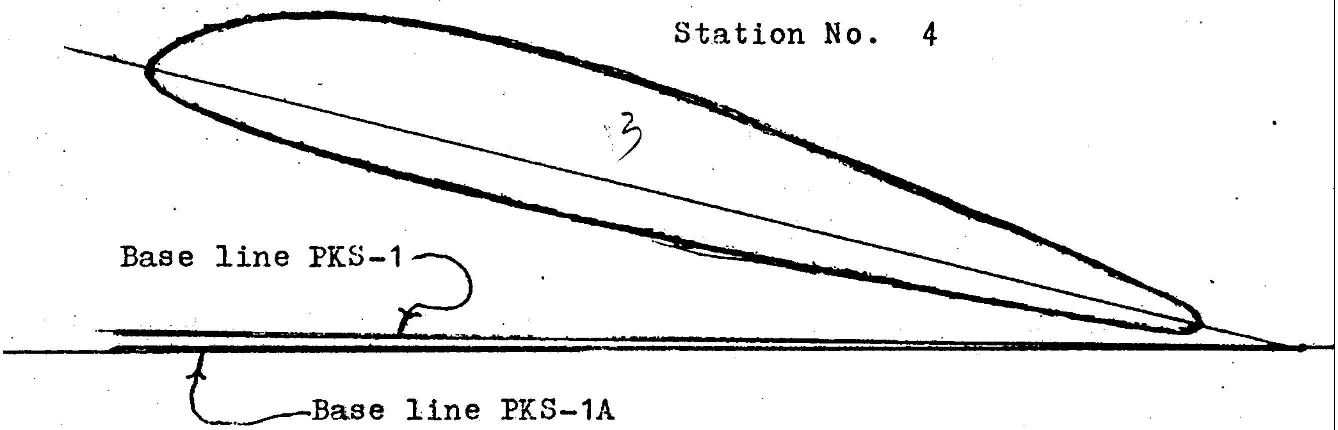


Station No. 3.

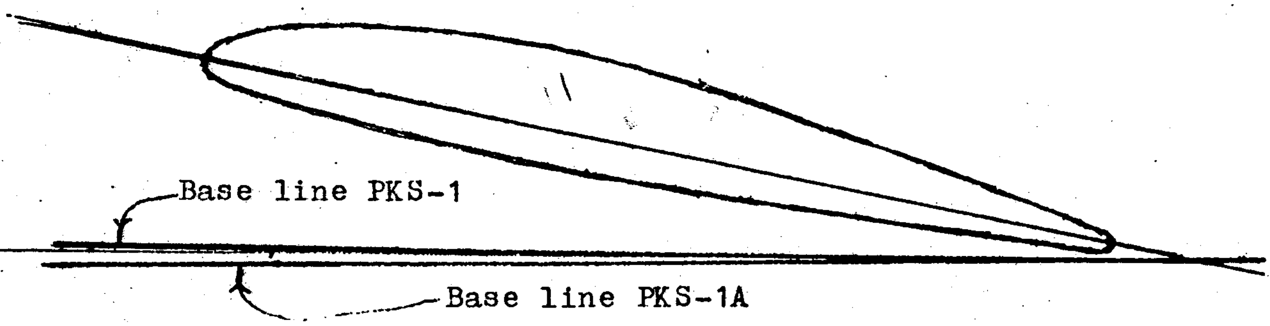
Airfoils and angles for propeller for Corvair powered Aircamper.

Design No. PKS-1 and PKS-1A

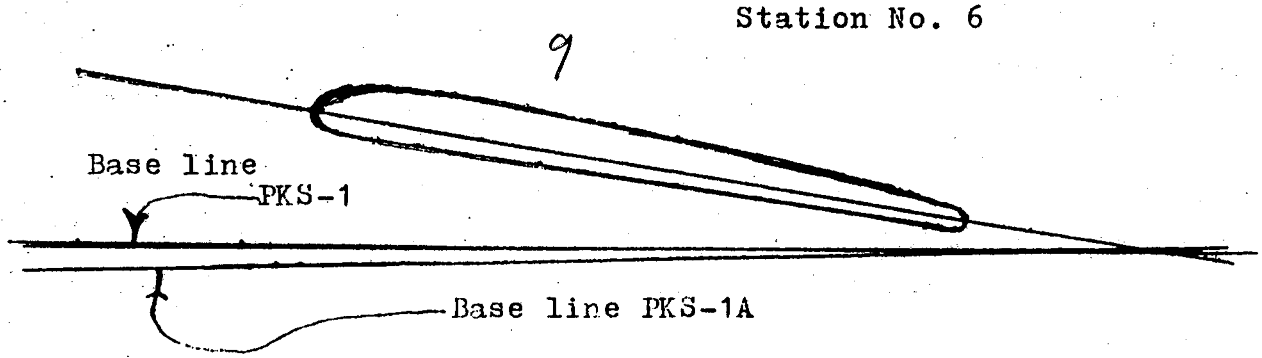
Station No. 4



Station No. 5



Station No. 6



How I make propellers.

Propeller for Corvair powered Pietenpol, how it turned out.

This propeller was finished and delivered to Vi Kapler at Cherry Grove in the last part of April 1980. It was tried on an engine on a test stand about the first of July and found to turn about 2950 static and to run very smoothly at all speeds. It was as a result of this static test deemed to be capable of flying a plane. Some days later it was put ON Bernie's personal Aircamper and flown. A few days later I received a letter giving his and Bernie's evaluation of its performance.

He said that on the day they tried it the temperature was 86 degrees F. and the humidity was high. Static run up at full throttle was 2950 and full throttle in level flight was 3500 at 100 MPH. At 3000 airspeed was 80 MPH, and cruise at 2900 showed about 78 MPH. It took 2600 RPM to maintain level flight at 67 MPH. Climb performanc was excellent at about, 1000 ft per minute. He thought it ran very smoothly and quietly He said Bernie thought that it needed a little more diameter or something to make an all around good prop of it.

When I got this letter I was surprised that the Corvair would take an Aircamper 100 MPH or that it would turn that prop 3500. I had only expected 3200 and 85 MPH. This Corvair engine must be more powerfull than I had thought. I had , on several occasions seen Corvair powered Aircampers fly and I was sure none of them had approached those figures. I got out my slide rule and put the figures on it and found that if those instruments were to be trusted this prop aready had all the diameter it needed, but should have more pitch. It was already going ahead 30 inches per turn and according to Mr. Tucker's article in SPORT AVIATION Jan. 1970 when this occurs efficiency falls of very rapidly. A few days later I drove to Cherry Grove and conferred with Vi about the matter. I reached the decision that I would carve a new propeller rather than try to alter the origonal. Besides I just might have a place where the origonal one might be used without any alterations.

Early in October I had the new propeller finished and took it to Cherry Grove. Vi was very interested and said that if I had the time we could go right out to the field and

How I make propellers.

Propeller for Corvair powered Pietenpol, and how it turned out.

try it on the test stand. I told him I had all day if need be. We had a litte trouble getting it to go on the hub, and a little more trouble getting the engine to start. When it went we ran it up several times to see for sure what it would do. It went to 2500 and ran quite nicely and smoothly. By this time it was noon so we went back to the shop and ate lunch. After dinner we returned to the field. This time we had Bernie along. We again had difficulty making the prop go on like it should but with the help of my jack knife and Vi's rat tail file we succeeded. This propeller had a diameter of 63 inches as compared with the first one and a pitch of 35 inches at the tips in place of the 30 inches the first one had. All of the pitch increase takes place at stations 4, 5, and 6. This propeller I call PKS-1 A. The diagrams on pages 67D and 67E show how this extra pitch is added and where. All airfoils are the same but the angles at stations 4, 5, and 6 are increased by the amount needed to achieve the results desired.

Vi took the plane up and flew it for about 20 or 30 minutes and landed. he taxied out right away and took off again and came back, landed, taxied in, and put it away. Bernie thought it ran very well, and Vi said he thought it worked as good as any he had flown. He said it turned 2600 static and 3100 straight and level. When he flew over at cruise it was quite quiet, but at full throttle it made quite a snarl. It still went to 100 MPH at full throttle, and would hold altitude at 2300. Bernie was anxious to have his plane flown more. He wants to get 1000 hrs. on it without any work on it except cleaning the spark plugs. Bernard was wondering how much these props would cost in lots of 40 or 50. They wanted to leave the prop on for a while to see how it worked.

I brought the other one back to Winona and left it at the airport for a man from Minneiska to try on a Revmaster powered Cuby he had amost completed.

How I Make Wood Propellers

Additional notes from the testing of propellers.

A man from LaCrosse, Wisconsin built a Sonerai II several years ago. In mid 1982 he engaged a certain pilot, also of LaCrosse to fly it for him and to give him instruction in it.

This plane is fitted with a VW Type III engine with 88 mm "bolt-in" cylenders giving it a displacement of about 1680 cc, the same as the engine on my "Fledermaus". It also is fitted with a supposedly more peppy camshaft than the "standard" one that my engine has. His propeller was purchased from an old well known carver. Performance of this plane with regard to takeoff and climb with both men aboard was extremely marginal. To my thinking this is not so surprising when one considers the plane's wingspan of 18 ft 8 inches, the combined weight of the two men of about 350 pounds and the engine of hardly more than 55 horse power. Speed though at full throttle in level flight was, in my opinion quite good, reportedly somewhat less than 140 miles per hour. The designer when consulted, recommended the purchase of another propeller with the same diameter but with two inches less pitch, from a different manufacturer. This was promptly done but changed takeoff, climb, top speed, and engine rpm very little. Figures compiled during tests were these:

Takeoff about 60 mph indicated.

Climb	at	80	mph	at	2900	rpm
Climb	at	90	mph	at	2950	rpm
Cruise	at	120	mph	at	3300	rpm
"	"	117	mph	at	3000	rpm
"	"	82	mph	at	2600	rpm
"	"	62	mph	at	2200	rpm
Down hill	at	140	mph	at	3600	rpm

These figures are indicated airspeed (not calibrated), rpm on an electric tach (calibrated at 2400 rpm), with both men aboard and the origonal 52 X 44 Hegy prop.

Both men repeatedly besought me to try my hand at carving a propeller for them but I was reluctant to do so because I felt that they probably already had one as good as could be made. The two men said that they would gladly give a little of the top speed if more performance at takeoff and climb could be achieved. As the three of us discussed

How I Make Wood Propellers

Additional notes on testing propellers.

the probable cause of the poor takeoff and climb of the plane we concluded that the origonal propellers were not allowing the engine to turn fast enough at takeoff and climb configuration for it to develop anything like rated power. On my "Fledermaus" in a climb at 90 mph my engine turns 3400 at full throttle, while on this builders SoneraiII the same size engine could turn neither of his propellers more than 2950. This seemed to tell us that these props were too big or had too much pitch or both. Finally I agreed to try my hand at whittling out a propeller for their ship.

The builder brought me a hub and a template to use for drilling the centering hole and the bolt holes in the hub. I used these to make a bushing and another template for them to use to drill their engine hub to fit the non standard bolt hole pattern of my propellers. This would make it possible for them to try some of the propellers from my "Fledermaus" on their plane, thus giving us a better idea of what diameter and pitch they need. Then I gave them my "Butter Paddle Special" 50 X 39 to try.

A few days after this I received two letters, one from the builder and one from the pilot, each almost bubling over with ecstacy over the unexpected improvement in takeoff and climb that had resulted when my "Butter Paddle Special" was installed. Expectations had sunk when at static runup it turned no faster than theirs had. After a consultation the two men agreed that in spite of the looks of things they would fly it anyway just to see what would happen. The pilot afterward reported that when he opened the throttle at the beginning of the runway, he had hardly gone ten feet before he could see the improvment in accelleration! Takeoff and climb were very noticably improved, and top speed seemed not to have suffered in the process. After one circut of the airport he landed and reported his findings. Both men then got aboard and returned to the sky. When they landed they were elated and reported the following statistics to me by letter.

Climb	at	85 IAS	3350 rpm	67%	advance	ratio
Climb	at	90 "	3400 "	72%	"	"
Level flight	at	118 "	3400 rpm	94%	"	"

How I Make Wood Propellers

Additional notes on testing propellers.

Level flight at	124 mph	3500 rpm	96%	advance	ratio
Holding level at	140 mph	4000 rpm	95%	advance	ratio

Note: By "Advance Ratio" I mean Distance traveled per minute, in feet, divided by Pitch in feet times **RPM.**

Takeoff and climb and top speed were all improved. A little vibration was apparent at about 3600 rpm.

When I read their letters I too was surprised that my "Butter Paddle Special" had so badly outperformed the two factory recomended ones. I attributed it to the fact that they may have had too much pitch,may have had too little blade area, the distribution of the pitch along the diameter of the blade may not have been correct, and that the engine had not been allowed to turn fast enough to develop its rated power. I have had people tell me that they had propellers that turned hardly any faster in the air than on the ground. These people usually complained of the performance they were getting too. I have seen ads in magazines telling of "almost constant speed propellers". I do not know how these are made. I do not know **WHY** either. It must be a "trade secret". I do believe if one insists on using such a propeller it must turn almost rated rpm at static if it is to do much for him.

After those men from LaCrosse tried that "Butter Paddle Special" on their Sonerai II I carved three additional propellers for it. They were all quite similar in design and all carved from mahogany. Variations were confined to differences in pitch and blade widths. Blade thickness and percentage of camber were all quite similar. These propellers I designated as: **BL-1**, 52 X 40: **BL-3**, 52 X 38: **BL-5**, 52 X 36. The "Butter Paddle Special" was 50 X39.3 .

One Sunday in March 1983 all four of these propellers were installed and flown one after the other and the performance recorded. The data gathered include takeoff run in feet, time required to climb to 3000 ft, speed straight and level at that altitude at full throttle and rpm at that speed. Barometric pressure was very close to 29.65 in., temperature was in the low 40's, the wind varied between 8 and 9 mph and almost straight down the runway. What will probably seem strange to many is that though these props varied in pitch from 40 to 36 inches and in width at the tips from 2½ inches to 4½ inches top speeds varied

Additional notes on testing propellers

only 3 mph. Distance to liftoff varied only slightly. Top rpm varied from 3900 to 4200 at full throttle in level flight. Time to 3000 ft varied from 5 minutes 12 seconds for the "Butter Paddle Special" to 4 minutes 34 seconds for the BL-1, but the B.P.S. seemed only to go 1 mph less at top speed. As the result of these tests the two men chose the B.L.-1 as the one they wished to keep, and gave the other three back to me. I was not present to see the testing of these propellers but received a letter from the builder of the plane informing me of the results. I had seen all but one of the props flown over my house and of them I believe the B.P.S. was the quietest. The difference in climb and take-off performance was most noticeable between the B.P.S. and the BL-1. The rest of the differences between the various model were quite small, so small as to lie almost completely within the margin of error of the instruments and one's ability to read them accurately and his piloting proficiency. I do not believe one should base one's choice of which propeller he should choose on the basis of a single flight, or on performance statistics alone. There seem to me to be other factors which also enter in. These are rather difficult to define.(For me, at least). These I might describe as pleasantness, or good naturedness, and also smoothness. After I have flown a prop 10 times or so I know better whether I like it or not. Sometimes I have a totally different opinion of it than I did the first time.

That the difference in pitch of these four propellers makes so little difference in the maximum speed of the plane is hard for many people to accept, but it is a fact of life nevertheless. On page 56 of the March 1974 number of SPORT AVIATION is an article by Ralph D. Korngold entitled "Climb" Prop or "Cruise" Prop? which everyone faced with the problem of choosing a propeller for his homebuilt should study well. For the designer and carver of props it is even more important. This article also shows how having a propeller that is too large or too high in pitch can reduce the amount of power your engine can deliver. A propeller carver who advertizes in SPORT AVIATION told me at Oshkosh this year (1983) that a large proportion of the customers who order propellers from him specify pitches that are too large.

From this experience I am inclined to deduce a number of things.

How I Make Wood Propellers

Additional notes on testing propellers

First: with a clean, fast, moderately powered plane the propeller must be optimized toward takeoff if one is to have good takeoff and climb characteristics.

Second: the engine must be allowed to turn nearly rated rpm at these times.

Third: that the VW engine does NOT turn "too fast" for good propeller efficiency, as some "experts" and non experts would have us to believe.

Fourth: that a propeller designed and carved by an amateur can perform as well or even better than one made by a professional carver.

An insight given to me by the proprietor of an automotive machine shop comes to mind at this time. It occurred in this way. I was complaining of the times when I had been told by professional machine shop operators that the job that I wanted done could not be done, and then some amateur,--- myself, or someone else had done it with even less equipment than the professional had. His answer was this.

"An amateur can always do a better job than the professional can, because he can take the time to do it right, while the professional must make a living at it."

Or maybe it's like the man told me at Oshkosh some years ago;

" The professional can make a propeller that will sell, but maybe you can make one that will perform."

To be honest though, I too was surprised that my props had so badly outperformed the factory recommended ones.

After receiving back the BL-3 and the BL-5 and the B.P.S. from the men from LaCrosse I put each of them on "Die Fledermaus" andflew each a number of times. Then I began to wonder how the BL-1 would have worked on it. At last curiosity got the better of me and I whittled another one of them to try on my ship and to take to Oshkosh 83 to show to the people there. When I tried it on my ship it turned to 3200 static the same as the other one had done on the LaCrosse Sonerai. When I flew it it took off like the B.P.S. had in the winter even thoughthis time the thermometer stood at 95 degrees F.

How I make Wood Propellers

Still more notes from testing propellers.

In spite of this prop's (the new BL-1) higher static rpm (350 rpm higher) it still cruised at 90 mph at 2950 and 18 inches of manifold pressure, the same as the B.P.S. does. Don't ask me how it does it but it does. I have flown it 42 more times since I have returned from Oshkosh and it still does it so I must not be dreaming. Consequently I am forced to admit that it is a better prop than the "Butter Paddle Special", especially for the Sonerai II and also for the "Fledermaus". I am including a plan for it a few pages later in this book.

Last summer (1982) I drove to Cherry Grove, Minnesota to visit Bernard Pietenpol. I wanted to give him one of these propeller books. I found him at home and in pretty good spirits in spite of the fact that he was quite badly crippled up with arthritis. I had known of him since the early 1930's but only during the last few years had become personally acquainted with him to any degree. When I told him that I had brought him a book telling how I carve propellers he said,

"I hope you havent come to take back that propeller you gave me last summer! That's the best one I have ever had on my plane"!

I replied,"No, that propeller is yours, I gave it to you. I came to give you this book to tell you how it was carved. Maybe you know someone who would like to carve propellers for Corvair powered Aircampers. This book can tell them how to do it."

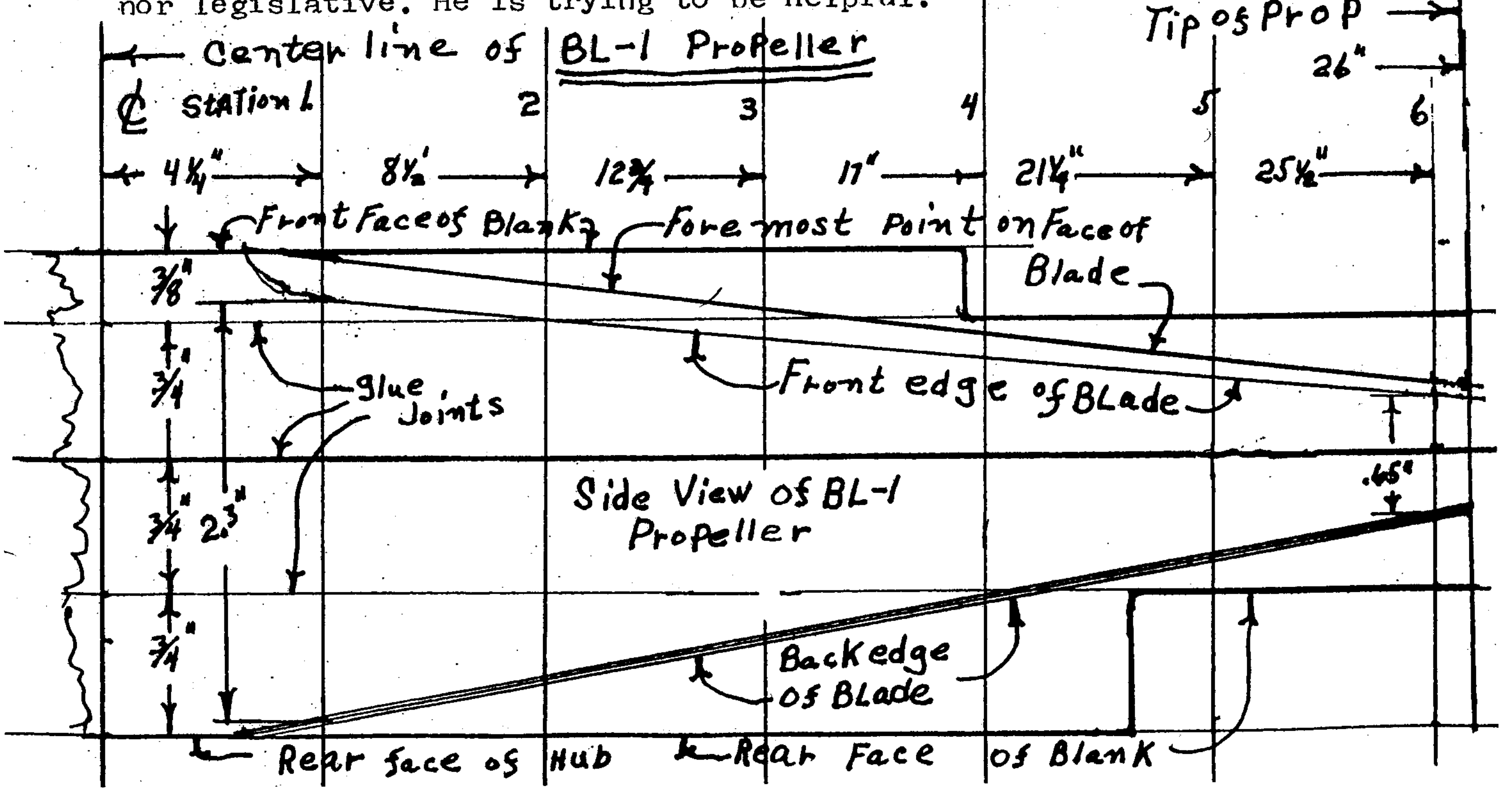
About six or eight months before a man from Chatfied, Minn. told me that Bernard had said that my propeller was the best he had ever flown on his plane.

I firmly believe that after all the articles on converting the Corvair written in "SPORT AVIATION" and many other places, and all the plans drawn, and all the speed reducers cooked up and pedaled for the Corvair, that the conversion by Bernard Pietenpol is "der alle beste", and--- the most practical!! Bernard was said to hold to the philosophy that that which you DO NOT put on an airplane does NOT weigh anything, does not hold it back, and CANNOT BREAK!!

I do believe that the VW and the Corvair can be very good engines for homebuilt aircraft, but they must be used with some discretion. It must be remembered that they are both really quite small

General Comments on Conversions

and Not really very powerfull. They are very definitely NOT 2800 cubic inch Pratt and Whitneys, nor are they O-320 Lycomings either! The plane one intends to use them in ought to be designed around them. One should keep his conversion as simple as possible , or nearly so. Reduction gears and superchargers are best left off. Starters too, maybe generators also. Be wary of the Hop-Up merchandise too. Some very few items do help but the very vast majority of it is NG! For best dependability the engine should be capable of maintaing altitude at cruise at about 50 percent power. Do not be stingy when building up your engine but by the same token, do not spend more money on it than a real aircraft engine would cost. Try to design your plane so that you can use a prop with a pitch diameter ratio of at least 75%. With a very slow plane it is harder to get good propeller efficiency. If the plane is very fast, good short field takeoff is harder to get. Let the VW turn about 3600- 3800 straight and level at full throttle but don't expect to cruise it there. If you have to cruise any aircraft at full throttle you're under powered! At least those are my sentiments. Some do it though. The Corvair should be let go to 3200-3400 top but don't cruise it there either. Remember the above advice is "General comments on conversions" and is not specifics. It is intended to help the amateur propeller carver to get reliable service and better efficiency from his engine-propeller package. The author is not trying to be critical nor legislative. He is trying to be helpful.



Propeller VS-S-3A, BL-1 52X40,
11-28-82 and 7-21-83

Station	1.	2.	3.	4.	3/4	5.	6.
Pitch	16"	27.5"	33.4"	37.1"	38.4"	39.2"	40"
% Pitch	40	68.75	82.5	93.	96	98	100%
Diameter	8.5"	17"	25.5"	34"		42.5"	51"
Radius	4¼"	8½"	12.75"	17"		21¼"	25½"
Blade width	4.46"	4.4"	4.26"	3.97"		3.48"	2.67"
Block width	3.83"	3.90"	3.94"	3.77"		3.30"	2.60"
Blade Depth	2.30"	1.97"	1.64"	1,31"		.98"	.65"
TANGENT	.60	.512	.42	.348		.294	.25

Pitch distribution curve

Propeller BL-1 11-28-82 turned 3,000 static Dec. 3, 1982 on Die Fledermaus

Propeller BL-1, 7-21-83 turned 3,100 static on a 95 degree F day, on Die Fledermaus and got off the ground very well and cruised at 90 mph at 2950 rpm and ran very smoothly.

BASE LINE

Propeller VS-S-3A, BL-1 52X40, 11-28-82 and 7-21-83

Station	1.	2.	3.	4.	3/4	5.	6.
Pitch	16"	27.5"	33.4"	37.1"	38.4"	39.2"	40"
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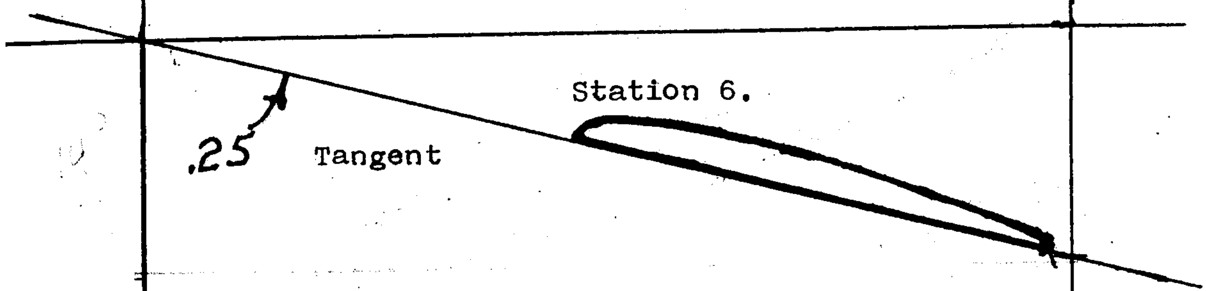
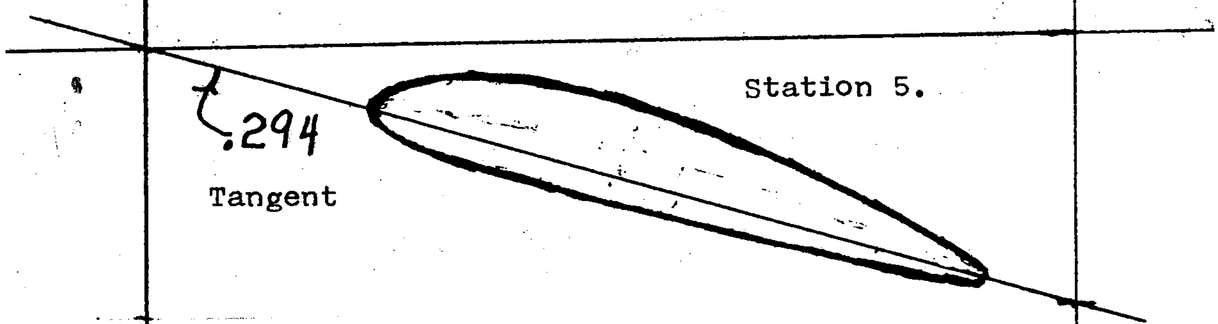
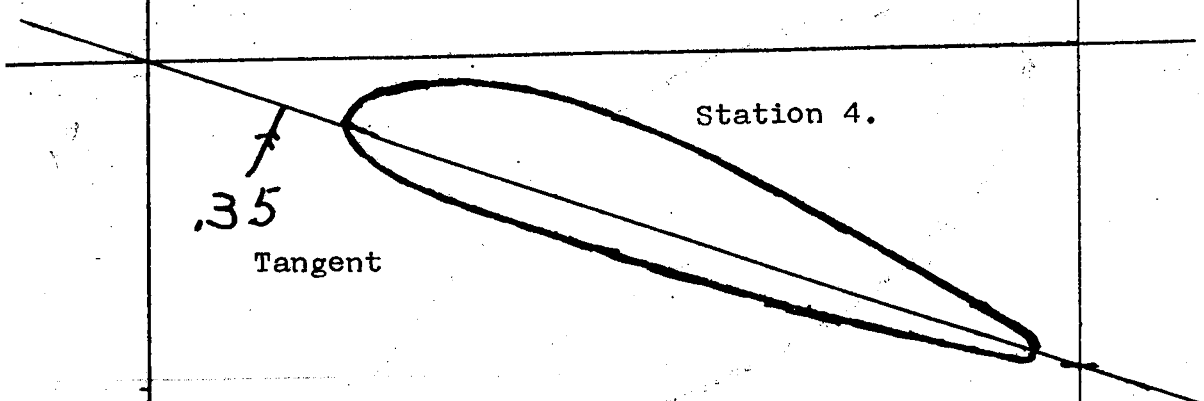
BASE LINE

Airfoil angles and sections. Of BL-1 PROP



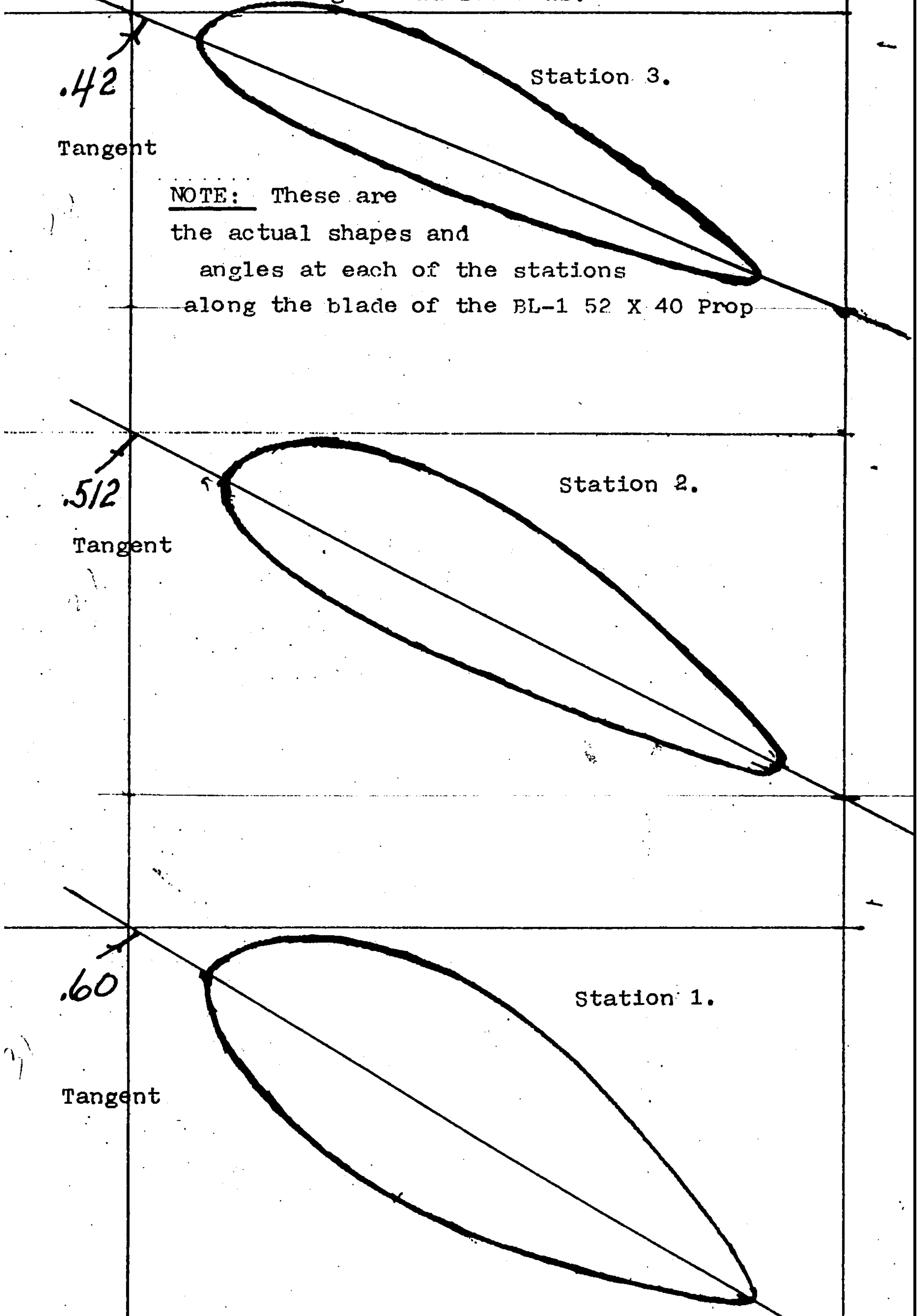
These are the actual shapes and angles at each of the stations along the blade of BL-1 52 X 40 prop





These are the actual shapes of the airfoils, of Propeller: Des no. VS-S-3A, BL-1 52X40, 7-21-83. These were take by contour gage from the finished prop and are subject to the usual tolerances inherent with contour gage work.

Airfoil angles and sections.



Propeller BL-1, 11-28-82 was origonally designed for use on Ed La Seuer's 1700 cc powered Sonerai- 2

How I Make Wood Propellers

How airfoil shape can affect pitch.

Did you know that the shape of the airfoil of a propeller can cause the pitch to be greater than the designer intended it to be?

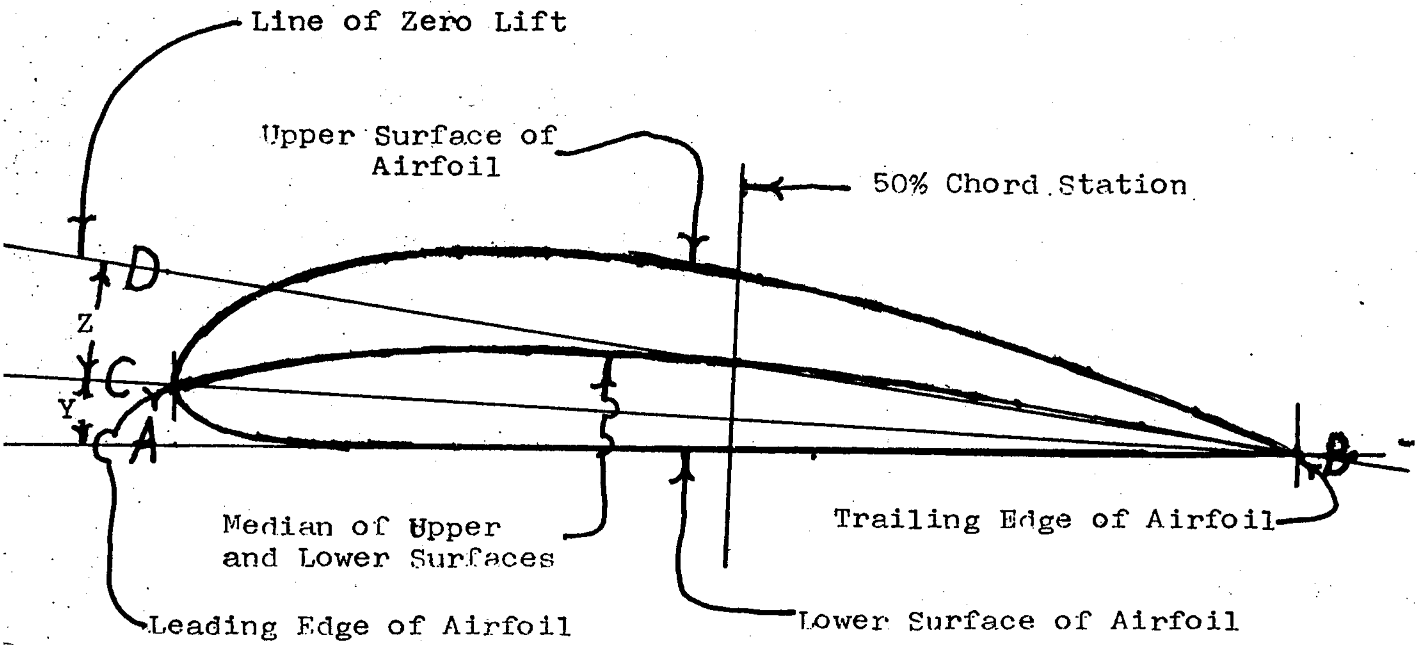
In various places in this book I discuss the matter of propeller pitch. How I calculate the approximate pitch needed. How I translate this into angles. How I vary the amount of pitch along the length of the blade. How I construct my airfoil templates so that the propeller I am carving will have the amount Of pitch that I want it to have, and not something else.

A number of times I have been consulted by people who owned experimental aircraft which they themselves had constructed , and several times by people who had puchased them. These aircraft did not seem to reward them with the performance that they had anticipated. The owners suspected that the propeller was the cause of their toubles. Usually the engine did not produce the rpm that was expected of it and takeoff and climb out was rather poor. The propellers on these planes had been made by well known (and advertised) carvers. I do NOT pretend to be a propeller expert or a trouble shooter, but I have in several instances been able to improve the situation for them more than just somewhat. I tell of some of these instances where I have been able to effect these improvements on pages 67B to 69I

In most cases the propeller seemed to have more pitch than it should. Oh,--,it may have had the right numbers stamped on the hub, but why didn't it work better? Probably because the "effective" pitch may have been considerably greater than the specifications may have led one to expect. How could this happen? To explain this requires us to review what I said in this book on pages 19, 20, 21, and 22, and to study again the article from the November 1973 number of SPORT AVIATION, pages 15 thru 20 entitled Application of Wood and Metal Propellers. I advise you especially to study what the author has to say about Pitch in the first column on page 19, and what he says about AIRFOILS on pages 20 and 21.

How I Make Wood Propellers

How airfoil shape can affect pitch.



Above is a typical airfoil many carvers would use at the 60 or 75% station on the blade. It is very close to the NACA 4415 or a Clark Y 15. About 90% of the lower surface lies on the straight line AB. For many of the older airfoils such as the Clark Y and the U S A series this line AB was considered the chord line and line of Zero incidence and all angles were measured from it. Just above this line AB, and intersecting it at point B (at the trailing edge) is line CB. It reaches from the extreme leading edge to the extreme trailing edge. It, like line AB, is straight. On the N A C A 4400 series and on most modern airfoils this line(Line CB) is the base line from which all angles of attack and incidence are measured. The external thicknesses and the amount of camber of the airfoil are also measured from this line CB. Just above this straight line CB, and intersecting it at both point C and point B, lies curved line CB. It is called the Camber line. It is equidistant from the top and bottom surfaces of the air-foil. The amount of curvature of this line in relation to its length, and where that curvature occurs is a very vital dimension of that airfoil as far as aerodynamics goes. It affects the value of the

How I Make Wood Propellers

How airfoil shape can affect pitch.

optimum (most efficient) lift coficient, the angle of maximum lift, and of zero lift, plus the pitching moment, and to some extent, the type of stall of the section. Moderate changes in the thickness of the section (distance between the upper and lower surfaces) affect the performance of an airfoil very little if this camber line remains unchanged.

Line DB is the line of zero lift coficient. It passes through the intersection of the Mean Camber line CB and the 50% chord station of the airfoil, and point B at the trailing edge. When this line is par-alell to the airstream, most airfoils develop very little or no lift at all. As I said at the top of page 21, on a propeller blade this is the line of Zero Thrust, period! If the plane goes faster than this the propeller is turning the engine rather than the other way around.

Looking again at our drawing we see Angle ABC. It is the angle between the lower surface of the section and the chord line. If we were to measure it with a protractor we would find that in this particular case it is about 2 degrees. This means that if we use line AB (the flat back side of the blade) as our reference, and measure our pitch to this line, our prop will have 2 degrees more pitch than if we were to use line CB (the chord line of the section). On the average propeller 2 degrees amounts to about 4 inch of pitch. When we consider that the difference in pitch between a "cruise" prop and a "climb" prop is often only 2 inches of pitch, one can easily see how this extra 4 inches could affect performance more than just noticably.

Now let us look once more at our drawing and consider DBA the angle between the Zero thrust line DB, and the base line AB, if that is what we are using. On the airfoil in our drawing it measures some-thing over 5 degrees, but the reports of many flat bottomed airfoils in a little book of airfoils I have, it shows this angle more often to be 6 to 8 degrees, depending on the thickness of the airfoil and the flatness of the lower side of it. A couple even went to 9 degrees. Figuring 2 inches of pitch equals 1 degree, this would add 12 to 16 inches to the "total" pitch of the propeller. You may say that the airfoils I am looking at in this airfoil book are not typical of those used on most purchased propellers, but I find that they are most typical. To illustrate I submit the following:

How I Make Wood Propellers

How airfoil shape can affect pitch.

A friend of mine had a Mustang II which he bought at a city about 200 miles south of here, It had been built by an older man who decided after he had flown it a few times that it was too fast and quick for him. After my friend got it home and had flown it a few times, he did some work on the landing gear which improved the ground handling tremendously. He now liked it very well except for its rather poor takeoff performance. It had a 135 HP 0-290 Lycoming which was supposed to turn a maximum of 2800 rpm, but turned only 1900 static and 2350 straight and level at 160 mph. His propeller (wood) had a name on it that is well known in homebuilder's circles, and carried the numbers **66 X** 74. These seemed to me to be about correct, as these were the numbers quoted in the magazine article mentioned in the middle of page 12 of this book, as being suitible for this engine on a T-18. Because of this I resisted his hints that I should carve a propeller of my own design for his plane, but finally I gave in.

One day he told me that he had removed the spinner and gave me the key to the hangar so that I could go in and take what measurements I needed. I was pretty well prepared and came back with angles, thicknesses, and widths for each of the 6 stations I had located on the blade of his propeller, plus the greatest thickness the hub could have without requiring longer bolts nor larger openings in his spinner for the blades. I had forgotten to take along my contour guage, so I could not copy the exact shape of the airfoils, but made good mental notations of their shapes. When I was back home again I put all this data together into tables, drawings, and diagrams, and made calculations so that I could visualize such things as pitch, pitch distribution, blade angles, and shapes, and airfoil sections, to compare with my proposed designs.

When this was done I found that his propeller, instead of having a pitch of **74** inches as stamped on the hub, had instead 80 inches, when measured in relation to the flat back surface of the blade. This factor alone could be enough to reduce the static rpm by 300. The airfoils, due to their shapes had cambers which added almost 7 degrees to the Zero thrust angle, instead of about 3 degrees like I think they should have had. This could have acted to cut the rpm another 150 rpm.

Why the carver made it like this, and the basic pitch so much higher than the figure stamped on the hub, I do not know unless he intended to reduce it somewhat after the customer had flown it a few times. He may also have taken too literally the performance figures quoted by the designer of the plane. It could also have been intended for use on an O-320, or an O-360 instead of the O-290 on this ship. A little more work with pencil disclosed that this propeller would have to be going ahead 100 inches to the turn before it would have reached the place where it would be developing zero thrust.

As a result of my study I carved two propellers for this plane. The first ended up with a diameter of 67 inches and 74 inches of pitch at the tip of the blade. Blades were quite wide especially at the tips. Static rpm went to 2100. Airfoils were designed and carved to have a camber of about 2% near the tips. This gave it a zero thrust pitch of 80 inches, about 4/5 the pitch of one that came with the plane. When flown on the plane it gave 2100 rpm at static, very good accelleration, takeoff and climb, and went to about 160 mph straight and level. When the stick was pulled back in level flight it would climb straight up for about 2000 ft like a Pitts. It would, however, overspeed quite badly in level flight, going to better than 3000 rpm I was told. It was what could be called an aerobatic prop.

Sometime later I hacked out another one also from mahogany with the same diameter but with enough higher angles and a little more camber to give it a zero thrust pitch of 90 inches, just half way between the pitches of the other two propellers. It gave very satisfactory takeoff and climb. The owner claimed that it would "true out" at 178 mph at 6000 ft at full throttle. This at slightly under 2700 rpm. On July 28, 1983 this fine airplane with its new propeller was destroyed when a friend of the owner tried to takeoff from a 1900 ft long farm strip, with a 1300 ft elevation, with two notches of flap, and an engine that was later found to have weak compression in several of the cylinders. The temperature at the time was 90 degrees F and the tank contained 25 gallons of gas. The plane left the ground but refused to climb and wound up in a dense stand of oak. Haply there was no fire, and the pilot escaped with scratches on his shins, but the plane was demolished.

Enough data, including airfoils and the angles for them are given on pages 69E, 69F, 69G, 69H, and 69I.

How I Make Wood Propellers

PLAN FOR WOOD PROPELLER LM1-C for MUSTANG II

At the bottom of this page is a side view of one of blades of the last propeller I made for that Mustang II I wrote about a few pages earlier. It and the next few pages following give all the information needed to carve a propeller like it. This plan shows laminations a being .80" thick. I made it that way because that is the way the lumber came from the yard. I necked the blades down a bit where they come out of the spinner because the owner did not want to enlarge the holes where the blades came out. I made the hub 4 inches thick to fit the length of his bolts. If you don't understand drawing go back to page 16A and study what it says about the one there.

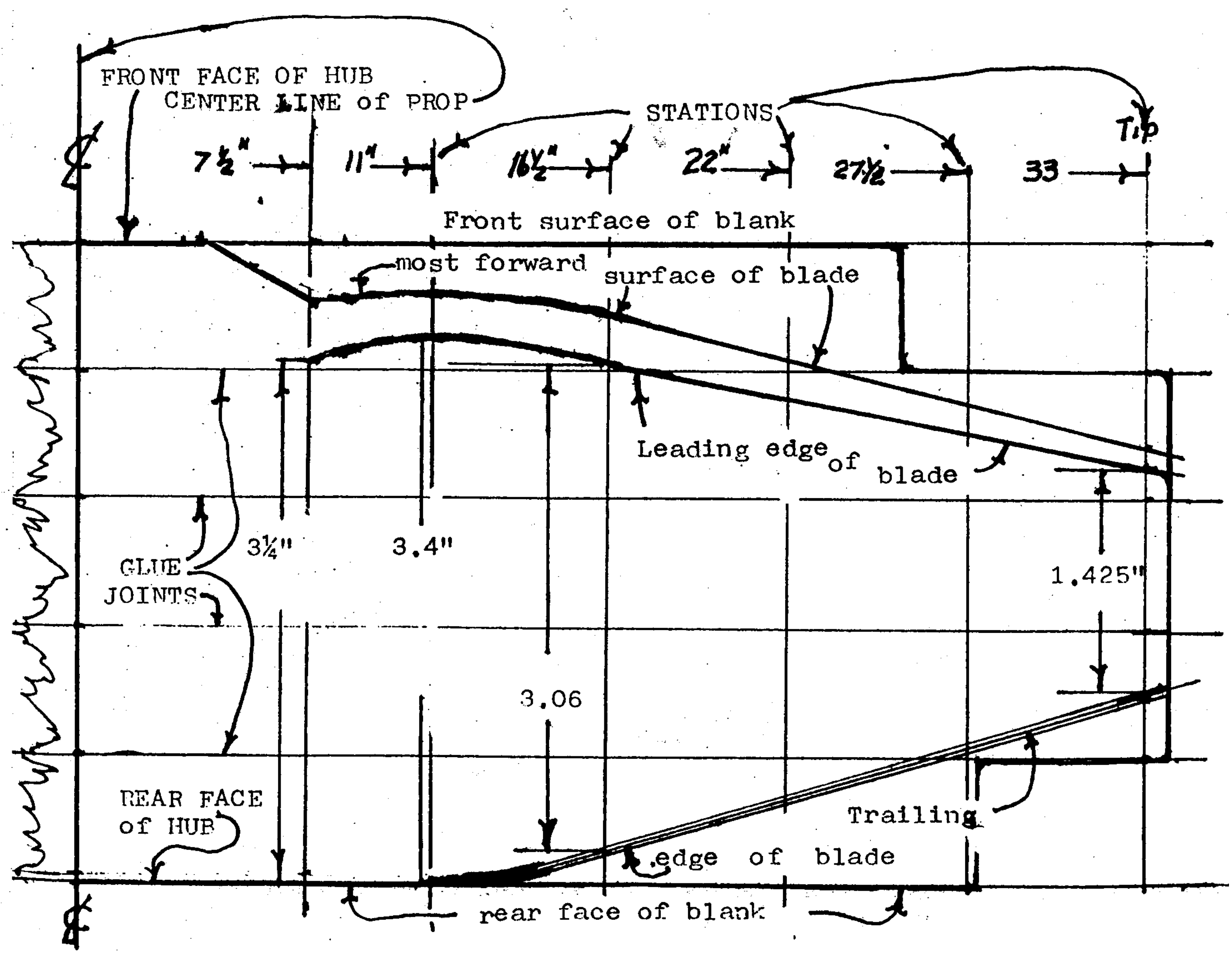
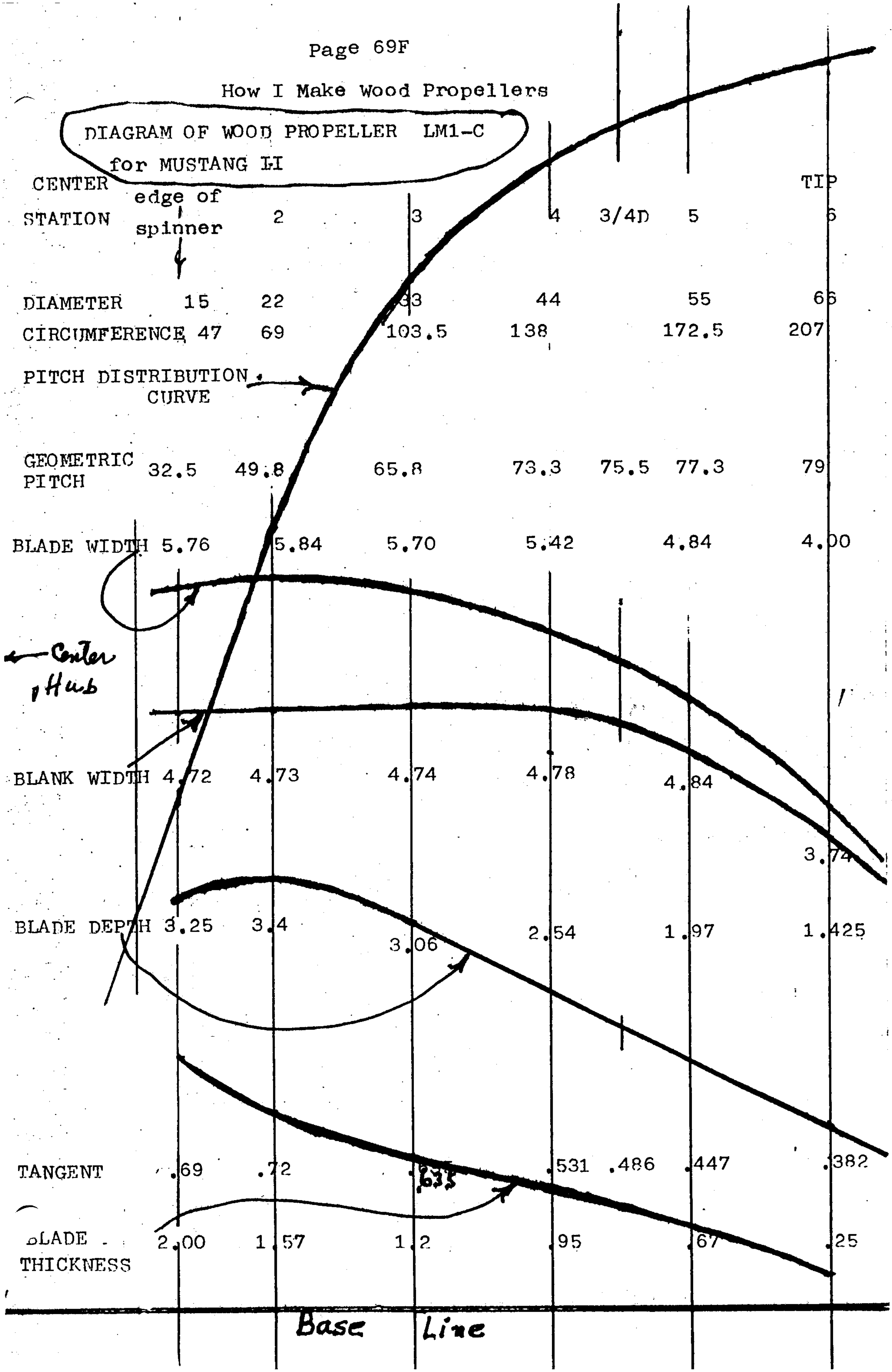


DIAGRAM OF WOOD PROPELLER LM1-C for MUSTANG II

CENTER STATION	edge of spinner	2	3	4	3/4D	5	TIP 6
DIAMETER	15	22	33	44		55	66
CIRCUMFERENCE	47	69	103.5	138		172.5	207
PITCH DISTRIBUTION CURVE							
GEOMETRIC PITCH	32.5	49.8	65.8	73.3	75.5	77.3	79
BLADE WIDTH	5.76	5.84	5.70	5.42		4.84	4.00
BLANK WIDTH	4.72	4.73	4.74	4.78		4.84	3.74
BLADE DEPTH	3.25	3.4	3.06	2.54		1.97	1.425
TANGENT	.69	.72	.635	.531	.486	.447	.382
BLADE THICKNESS	2.00	1.57	1.2	.95		.67	.25



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PITCH DISTRIBUTION CURVE							
GEOMETRIC PITCH	32.5	49.8	65.8	73.3	75.5	77.3	79
BLADE WIDTH	5.76	5.84	5.70	5.42		4.84	4.00
BLANK WIDTH	4.72	4.73	4.74	4.78		4.84	3.74
BLADE DEPTH	3.25	3.4	3.06	2.54		1.97	1.425
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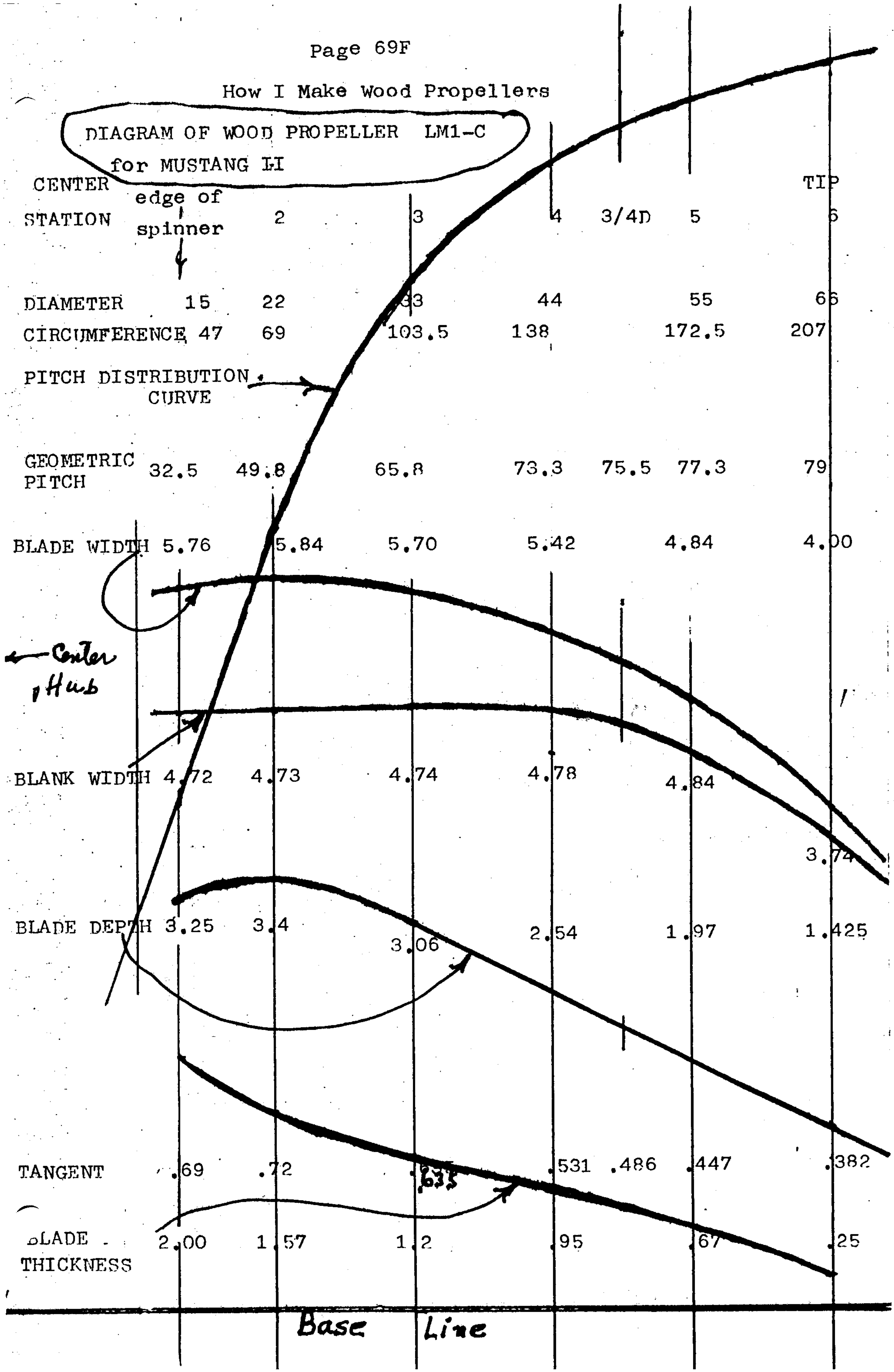
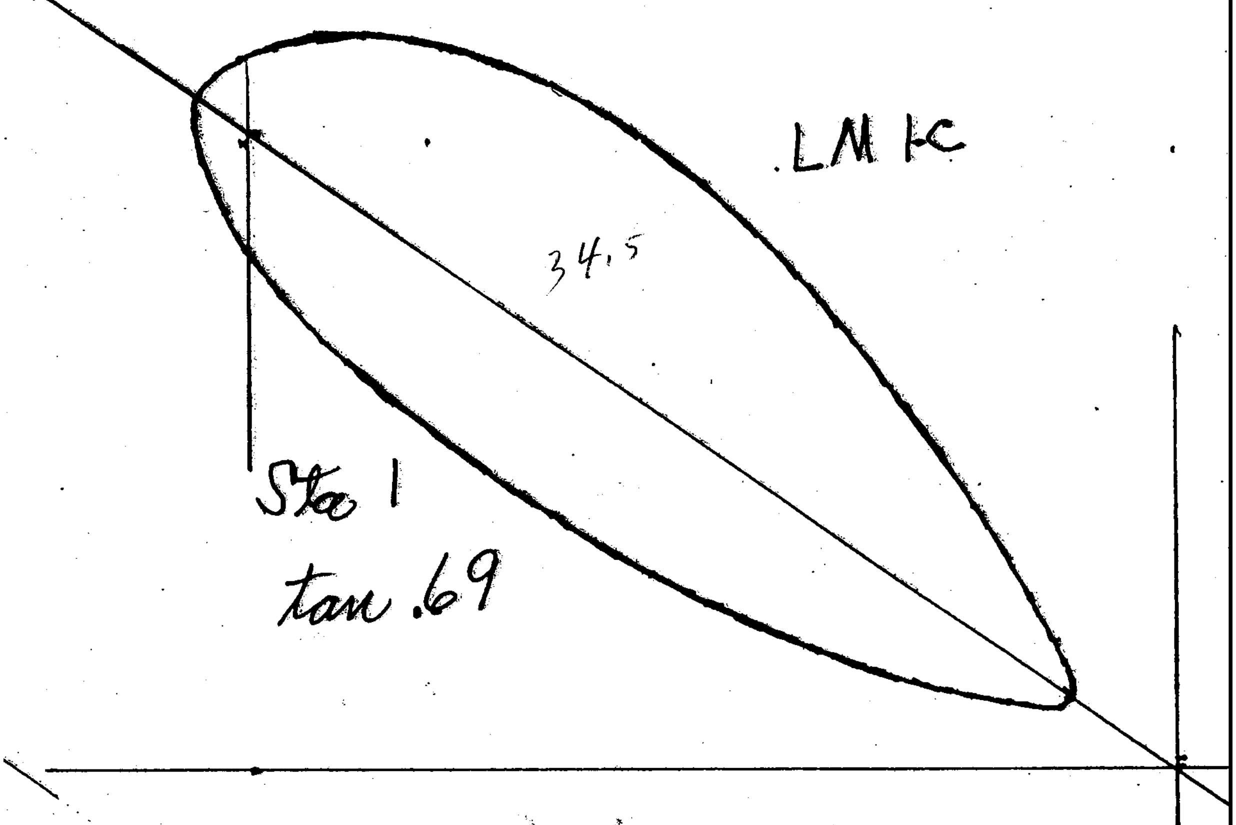
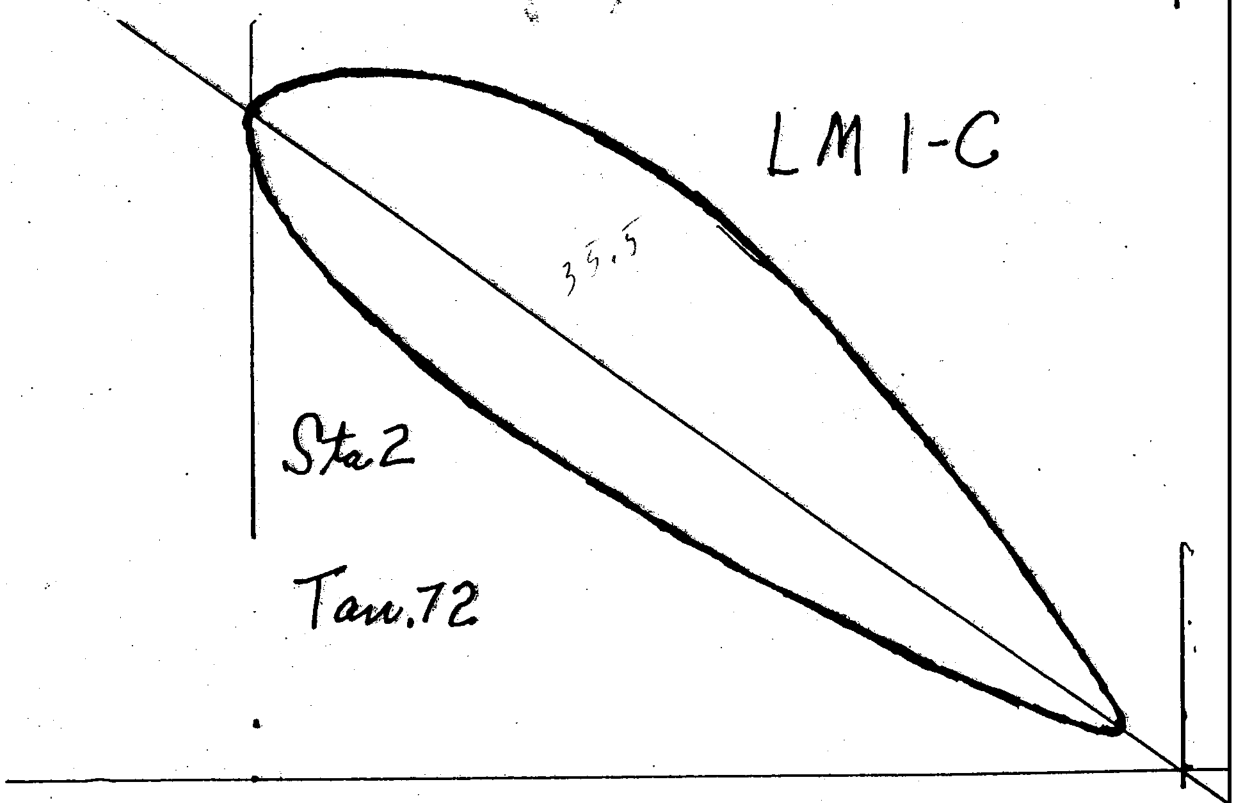


How I Make Wood Propellers

Airfoils and Angles for LM1-C Propellers





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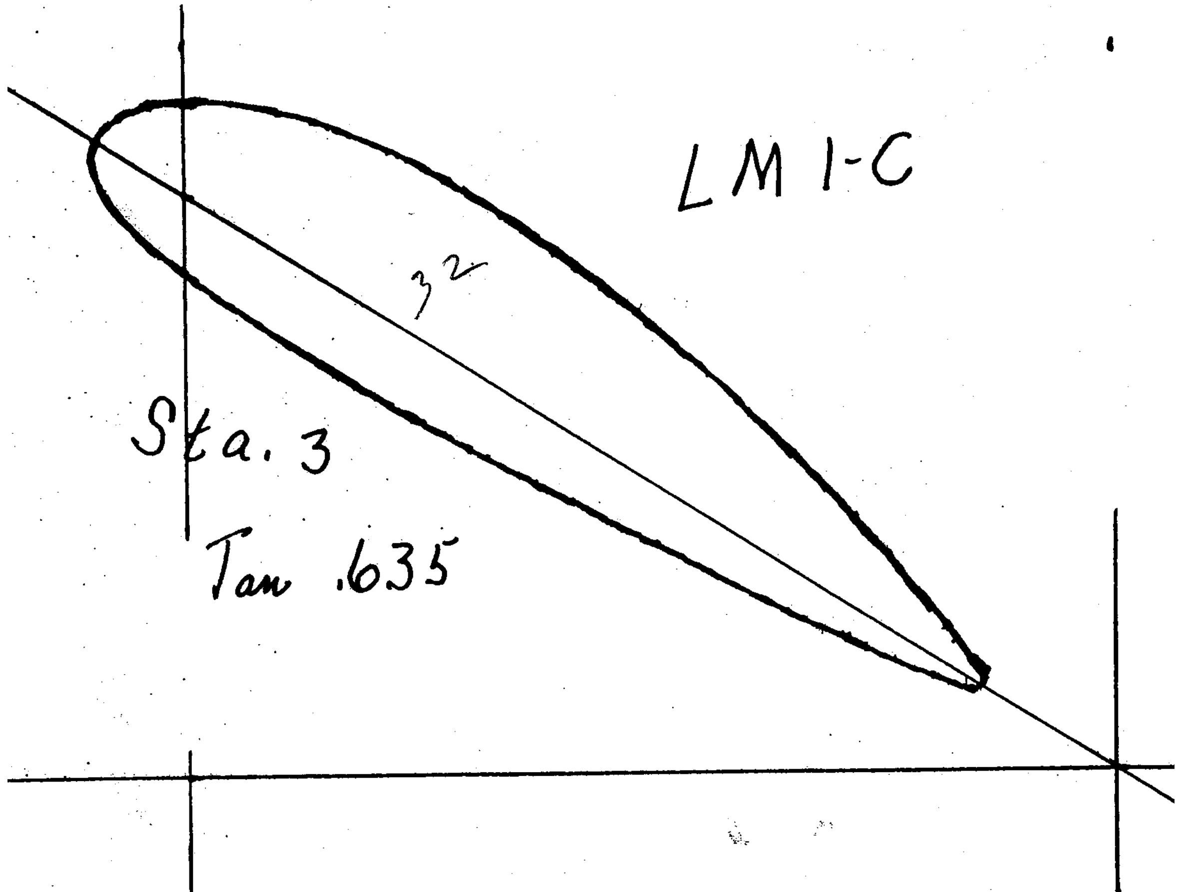

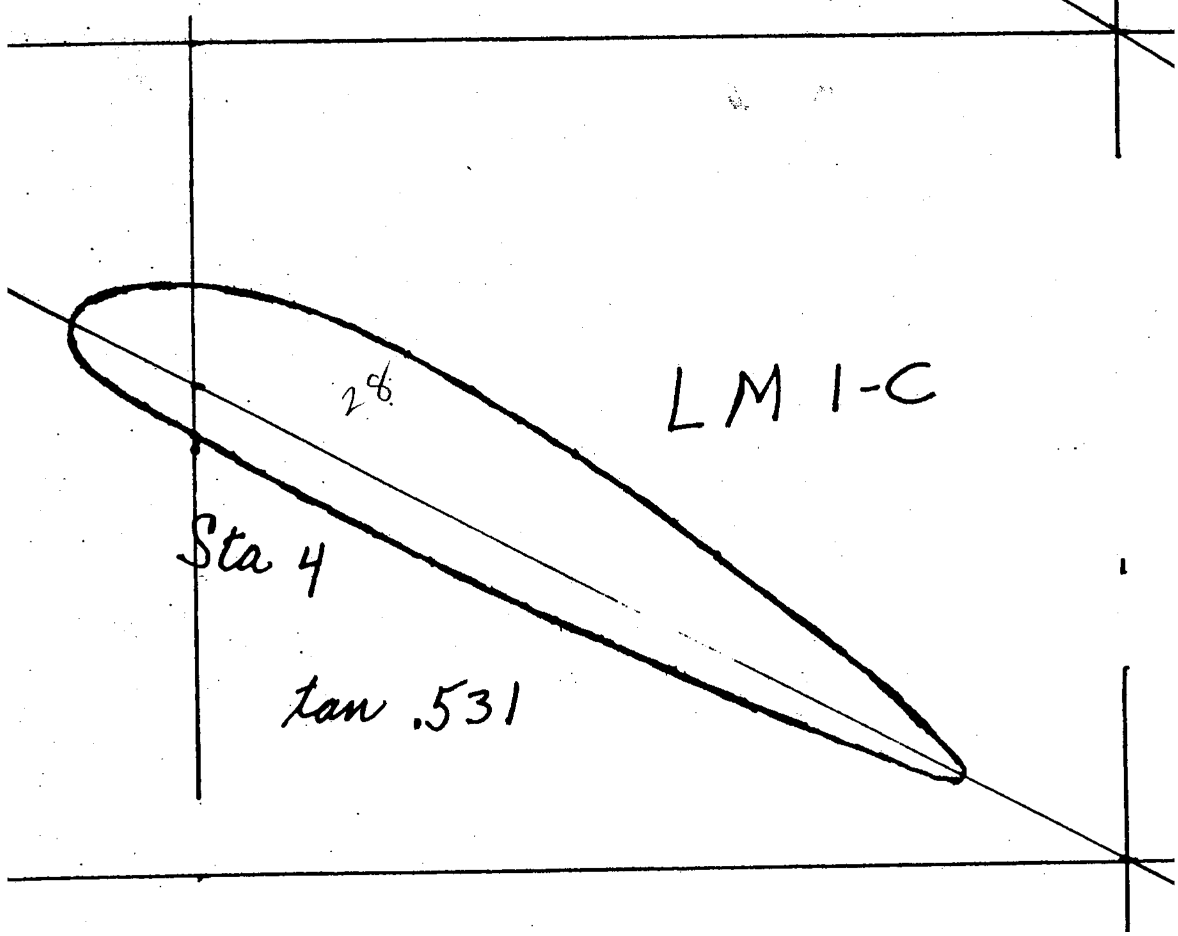

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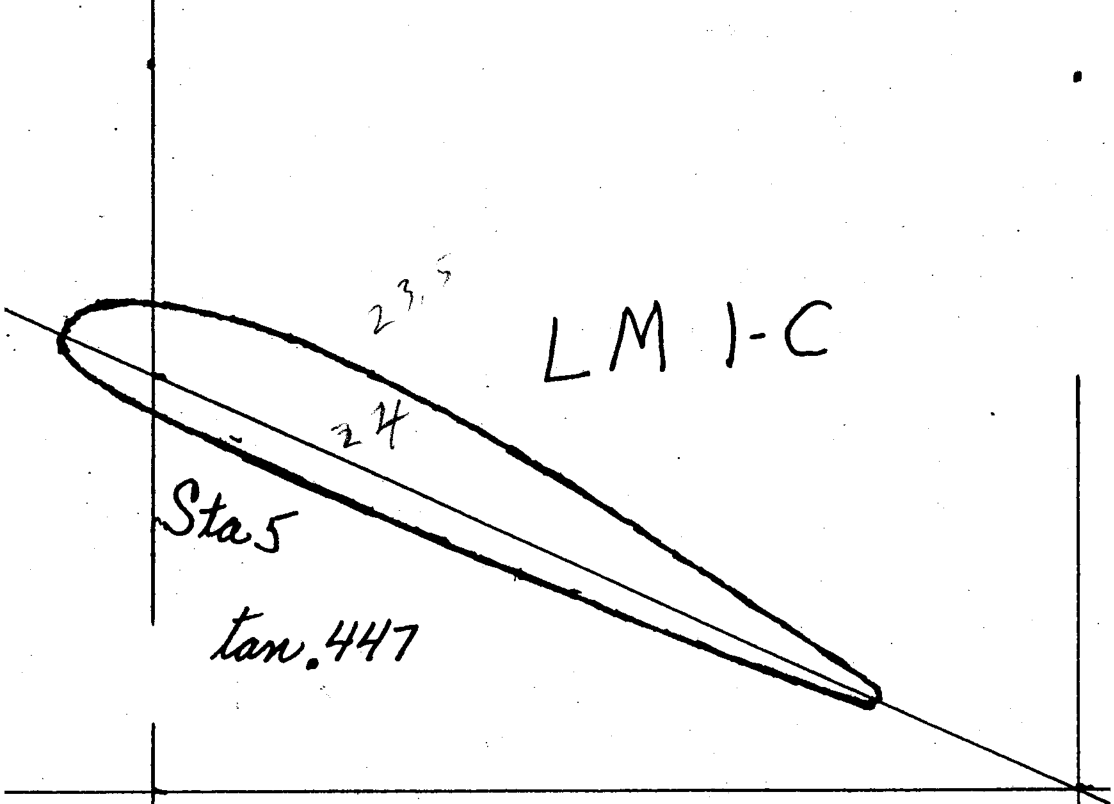
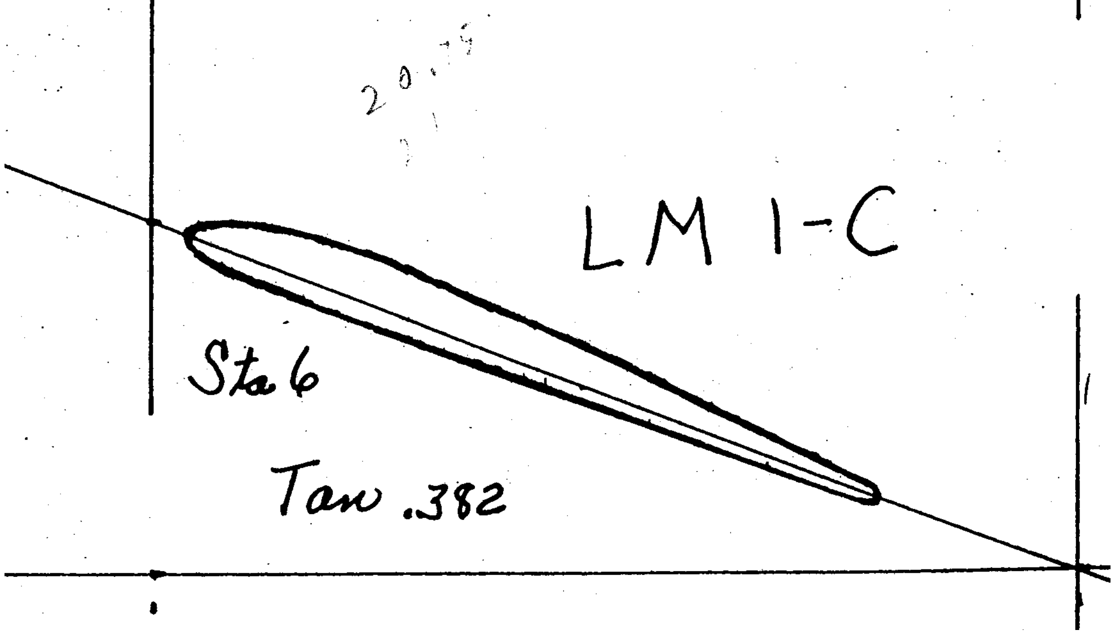




How I Make Wood Propellers

Plans and specications for the "Butter Paddle Special".

Some pages back I gave a report of the results of tests made with a propeller called the "Butter Paddle Special" on a Sonerai II. Said propeller had been carved in 1980 and flown for a couple of years with quite good results on my "Fledermaus". Maybe some one would like to see the specifications of it with the idea of copying it or perhaps adapting it to another plane or engine or both.

50 X 39 Butter Paddle Special ---- 6-13-80 --- Specications

Dimensions are in inches.

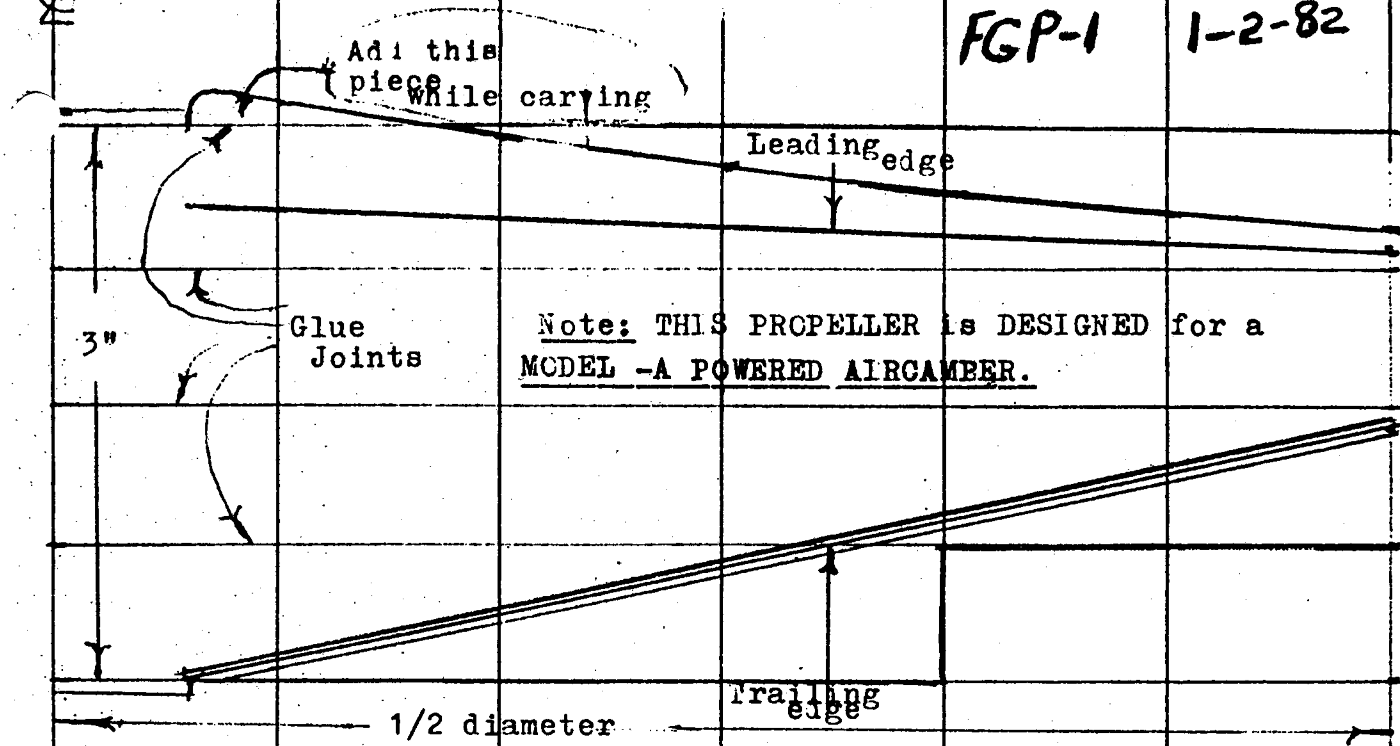
	1	2	3			5	6
Station	1/6	1/3	1/2	2/3	3/4	5/6	1.00
Diameter	8.33	16.66	25	33.33	37.5	41.66	50
Circumf.	26.16	52.33	78.54	104.64	117.6	130.92	157.08
% of full pitch	40%	66.66%	80%	88.9%	92%	95%	100%
Pitch	15.7	26.16	31.4	35.	36.5	37.8	39.4
Tangent	.60	.50	.40	.335	.31	.285	.25
ANGEL	31	26.5	21.75	18.5	17.25	15.75	14

Blade Depth, see drawing for the meaning of this and other dimensions.

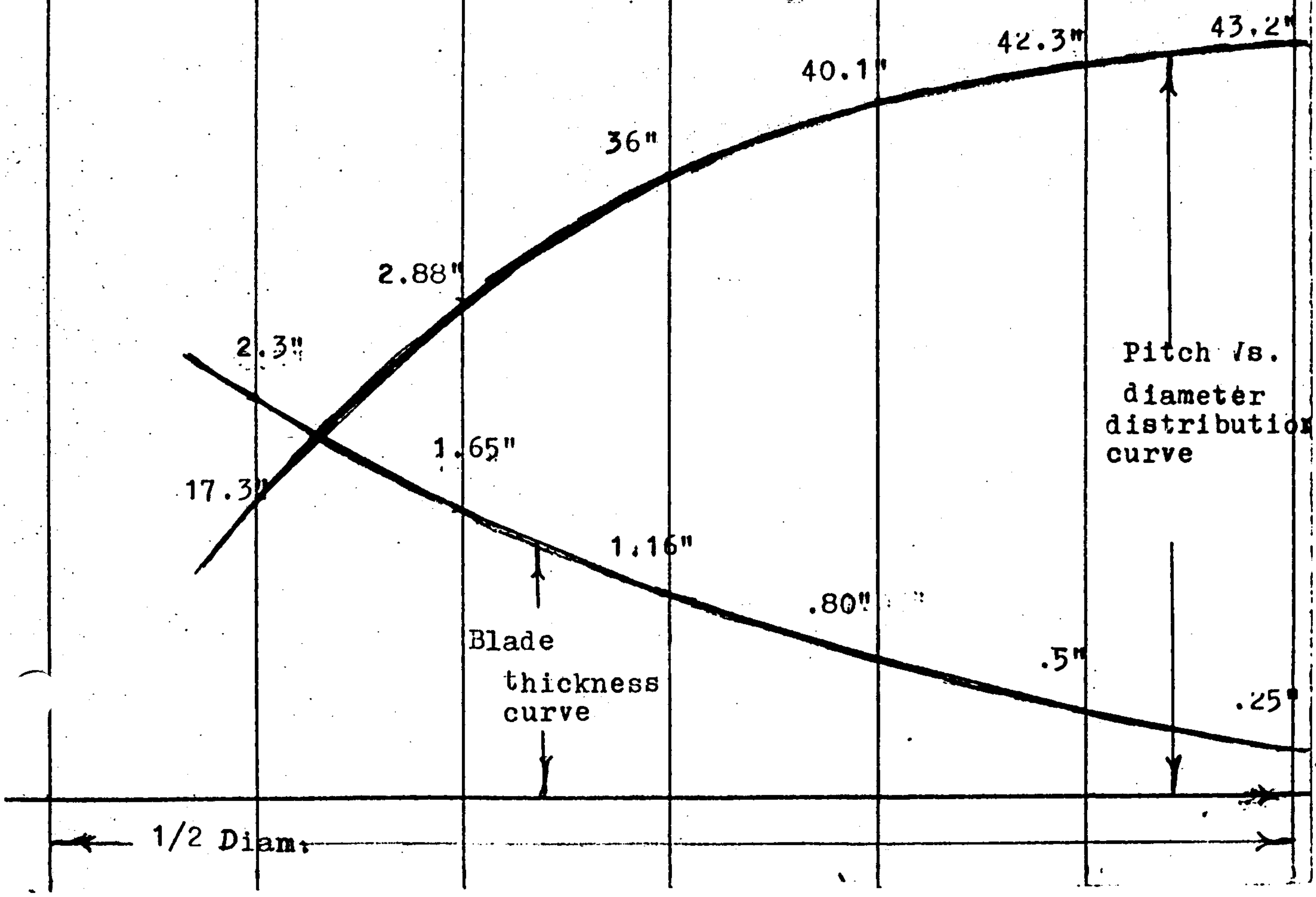
	2.50	2.20	1.90	1.60		1.30	1.00
Block Width	4.17	4.50	4.73	4.75		4.50	4.00
Blade Width	4.87	4.99	5.09	5.00		4.66	4.13
Blade Thickness	1.60	1.15	.75	.60		.45	.30

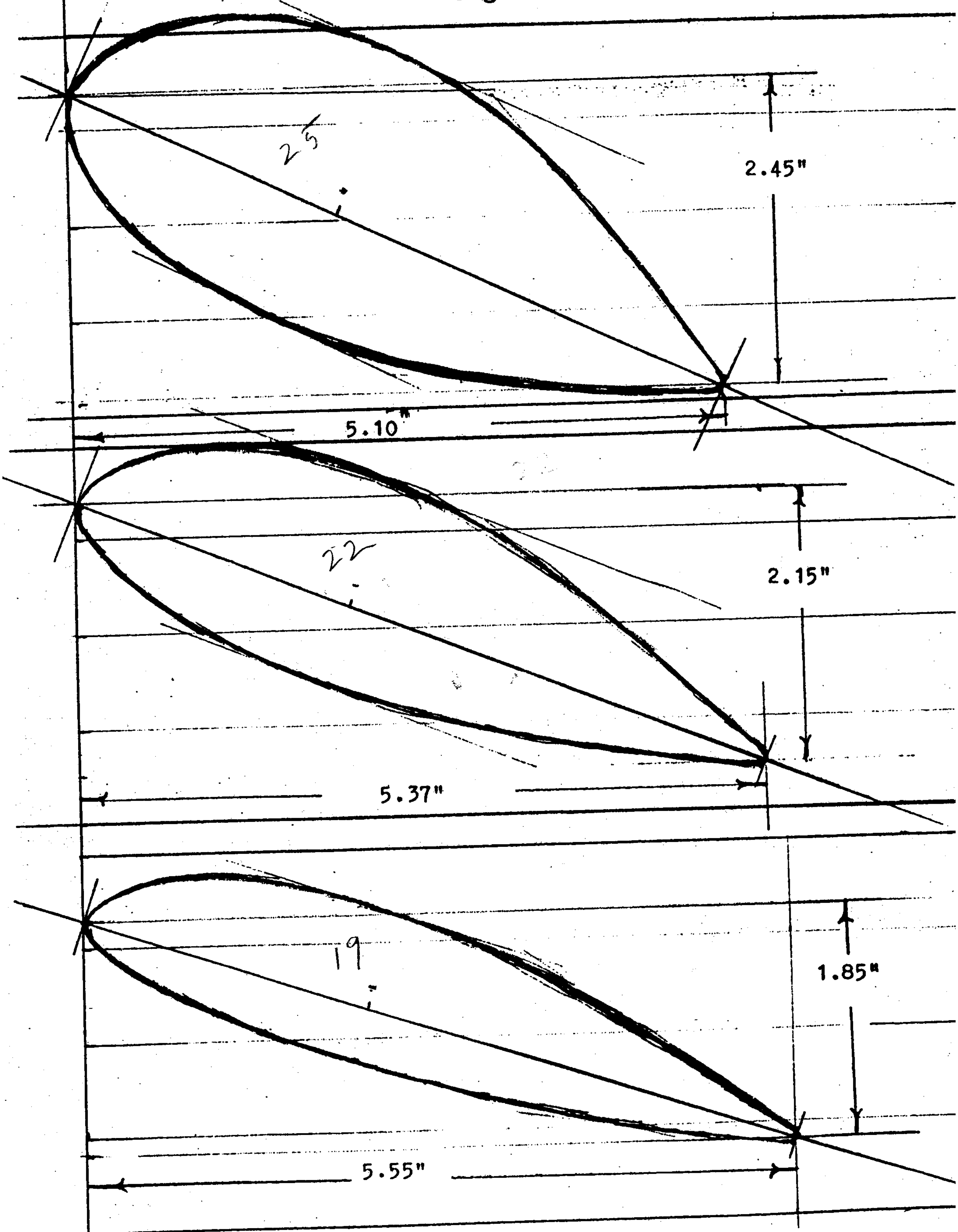
These specifications are subject to the usual wood working "tolerances" but are generally quite accurate. When the final finishing cuts are done, the various waves, bumps, and other discrepancies from a smooth contour are removed, so that lines and surfaces on both sides of the blades flow smoothly, and the propeller balances in all positions, dimensions and shapes will be slightly different from those shown.

Basic angles and airfoil sizes and shapes appear on the next several pages.

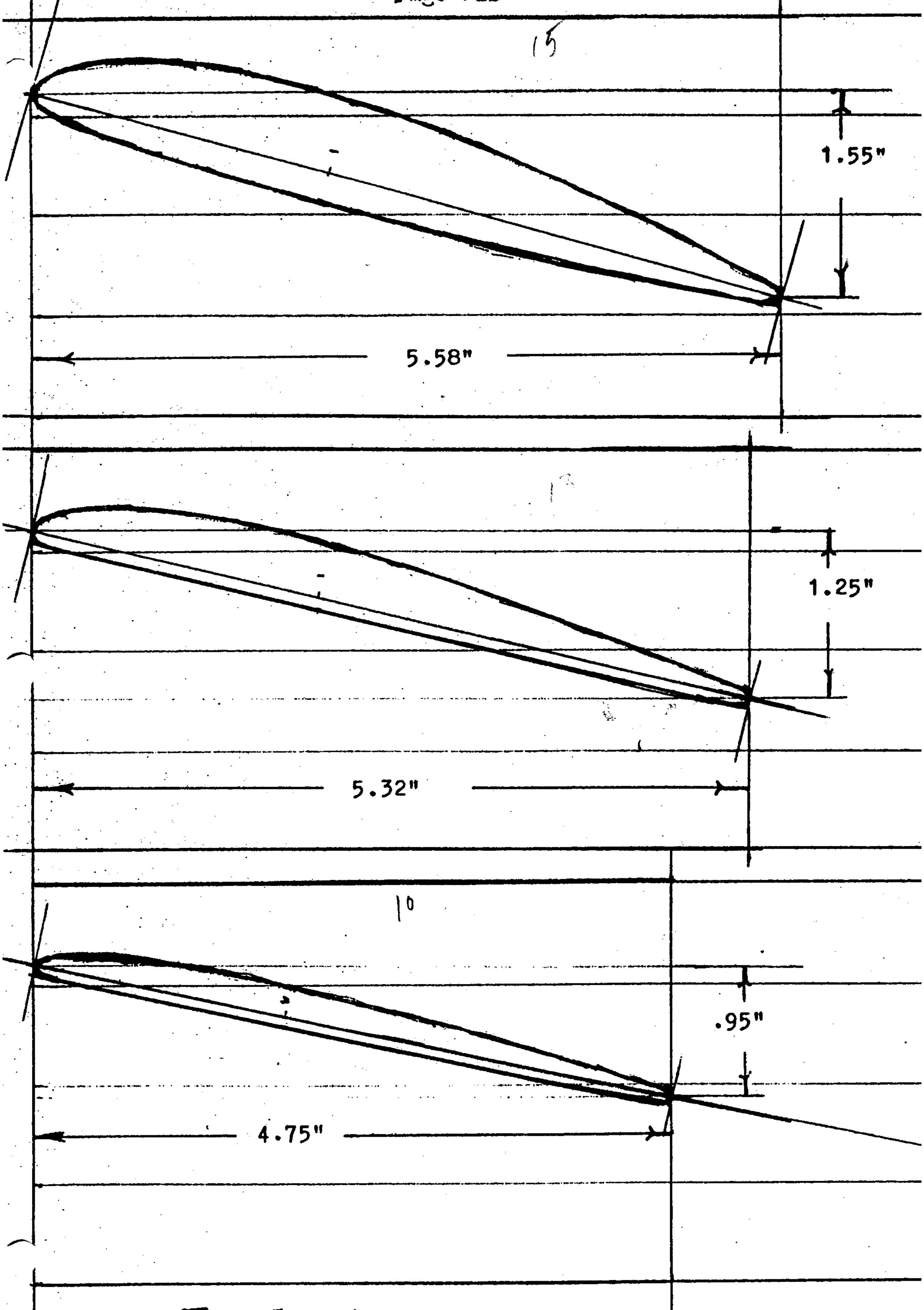


Station	1	2	3	4	5	6
Diameter	11½"	23"	34½"	46"	57½"	69"
Circumf	36"	72"	108"	144"	180"	216"
Pitch	17.3"	28.8"	36"	40.1"	42.3"	43.2"
% of pitch	40%	66.6%	83.3%	92.8%	98%	100%
Tangent	.48	.40	.333	.278	.235	.20





FGP-1 1-2-82



FGP-1

1-2-82

How I Make Wood Propellers

SUMMARY

Up to this point I have said very little about tipping on blades to protect from wear caused by rain while in the air or long grass when on the ground. I know from experience that prolonged flight through a light drizzle can wear the blades of a wood propeller considerably. I have been told that flying through a rain can take off so much material that enough thrust to keep the plane in the air can no longer be produced! For this reason I avoid flying in rain, and if caught in a drizzle throttle back as much as I can to minimize the damage. Landing where grass is tall usually does not hurt the untipped propeller if one does not taxi through it. Taking off where the grass is just a little long can do a lot of damage. Tall grass can take the blades down alarmingly in a very short distance! I have worn blades so badly taxiing in tall grass that I had to glue on new wood and recarve them. Fiberglass on the blades will reduce this kind of damage but will not prevent it completely. I have never applied brass tipping to a propeller. It reduces performance and also I feared it might come off. Remember one cannot repair a propeller while in the air. There is no place to stand.

Last summer I bought a roll of aluminum body tape (for cars) like one of the men at the propeller carving demonstration suggested as being useful for this purpose. I put a piece about eight inches long on each tip of the BL-1 prop that I am now using on "Die Fledermaus". It seemed to be sticking well and doing its job pretty well. One evening after I had flown about 9 hours with it I was about eighteen miles from home and not over particularly hospitable territory when the propeller started making a loud fluttering noise. Suddenly the noise quit and the engine began to vibrate quite severely. I quickly reduced power and after appaising the prospects below, headed for home using just enough power to avoid losing altitude too rapidly. When I had covered ten miles I could have landed at Holland Airpark, but things were going pretty good and I still had plenty of altitude so I continued on. After I landed at home, just as I had expected, the tape was gone from one tip. The other was as good as ever. I tried to peel the remaining one off but it would not come. I had to scrape it off. Why this one stuck so tightly while the other came off in flight beats me. Perhaps it was because I put them on without removing the varnish, or moisture from the wet weather had gotten under it.
I did not replace them. Eighteen miles is far enough to fly with aluminum

SUMMARY (continued)

tape on one tip and not on the other. Sometime though I might try Kevlar.

I am very glad that I designed and carved that BL-1 propeller for Ed La Seuer's Sonerai II(pages 68A through 68J). That design also performs very definitely better at takeoff and climb; and equally as well at cruise as any other I have tried on "Die Fledermaus" to date. It runs smoothly at all speeds but may be noisier than some to people on the ground. If I had not whittled it for Ed the both of us would still be struggling harder to get off the ground than we do now. I am also glad that I whittled the propellers for Mr. Pietenpol and for the owner of the Mustang II that I tell about a few pages back. I believe I learned a number of things from those experiences. I am led to believe some homebuilders may have given up and abandoned otherwise good designs or put up with so so performance just because the particular propeller they were using was not well suited. The maker of the propeller may have been famous and successful(fiancially) but if it was not right for the particular plane-engine combination results can still be disappointing.

As a result of these and other experiences I would urge the serious would-be propeller carvers to be sure to read those propeller articles from SPORT AVIATION that I recommend on pages 11, 12, and near the bottom of page 68D. I feel that the designer-carver should have these articles in his posession either by purchasing the magazines or by obtaining photocopies of them, so that he can refer to them from time to time. They contain so much valuable material that the reader will recognize the importance of only a portion of it at the first reading. They have to be studied and restudied from time to time.

I have not carved any new props since Oshkosh 83, nor have I designed any for anyone else. August and the first week of September were spent revising, printing, and assembling 30 copies of this book and mailing 25 of them to people I met at Oshkosh. four more were disposed of locally to friends and relatives. "Die Fledermaus" was not taken on any really long trips this fall, but I did make a number of flights of almost three hours duration each over parts of Wisconsin,Iowa, and Minnesota. Between December 4, 1982 and December 4,1983 92 hours were put on the tachour meter. It has been flown 519 times to date, at least around the patch. All but three of those times by me.

SUMMARY (continued)

In this book I have made an effort to answer the questions (in writing) that many people at Oshkosh had put to me while I was there demonstrating my methods of carving propellers for homebuilt aircraft. I do not make the claim that my way is the only way it can be done, nor that it is the best way it can be done. Neither do I state nor imply that this is the way that you should do it . I do state emphatically that if you should choose to use the methods described in this book to carve propellers for yourself or for anyone else, you must do so at your own risk, not at mine. This is because I would have no control over the quality of the workmanship, nor of the materials used, nor yet of the use that the resulting product might be put to.

The second point that I wish to make clear is that this book is not for sale, so please don't try to order it from me. It was written so that I might give it to those to whom I might choose to give it, rather than to sell it to make money on it.

The 21 different VW propellers mentioned in this book were all produced and tested by me, but only one of them was allowed to go to full RPM in level flight . None was ever used in any kind of aerobatics, nor in a shallow dive at full power. The propellers described in this book designated as PKS-1, and PKS-1A, were designed and produced for testing on a Corvair powered Aircampe The results given in this book were those reported to me by the test pilot, plus those which I myself observed the time when I was present. I, personally saw propeller PKS-1 flown once on the Revmaster powered Cuby, and can attest only to the fact that it seemed to turn about the proper speed, and that it appeared to takeoff and climb quite well. I do NOT recommend it for any kind of aerobatics, nor for any operation whatever above 3500 RPM.

Propeller design FGP-1, 1-2-82, is intended for testing on a Model-A powered Aircamper. Said propeller is not yet completed, nor is the engine nor the plane on which it is to be mounted, so no test results are yet available. Whether this propeller desig will need"adjusting"to a larger or a smaller diameter must wait at least until it can be mounted on the engine and run.

Concerning the design of the five blade propeller on pages

How I make propellers.

SUMMARY (continued)

66,67 , and 68, I have these remarks: The five blade propeller shown in the pictures is the only one I have ever built. It was made with laminations 3.2+ inches wide and .212 inches thick. Theoretically they should only have had to be 2.85 inches wide but the extra .4 of an inch was needed to take care of " manufacturing tolerances" accruing during the gluing process. The technique shown one page 67 was used for joining the laminations at the hub. As each layer of laminations were added the pattern was shifted two blades (2/5 of a turn) to the right, thus making four turns of the pattern, plus a little more, to get the eleven layers down. Each piece was carefully pre-fitted before gluing was begun. The assembling and gluing took me three hours from the spreading of the first glue until the clamps were tightened. I consider this to have been too long a time. Only one half of the laminations should have been laid down at one gluing or else a helper should have been employed to get the job done sooner. Because of the width of the laminations the diameter of the resulting hub could be five inches. There is some doubt in my mind as to how much confidence one should place in such an arrangement, but obviously, it must have held because so far no blades have been shed. I wish to make clear though, that 3400RPM (full throttle in a climb at 90 MPH) was as fast as I ever let it turn. I believe that if I should ever make another of these five blade propellers I would use laminations 4 inches wide instead of the 3.25 inches of the origonal, thus making the hub 6 inches in diameter instead of 5 and thereby, hopefully, somewhat stronger.

If you want to make people notice you when you taxi up to the ramp at a strange airport , a five blade propeller can help. If everything is done right, very little, if any, performance need be lost,

In final summary, I wish to say that the design and carving of experimental wood propellers is really not very difficult once one understands it. It does contain risks, though, just as involvement with any kind of aircraft, experimental or approved does. Therefore, I ask that if you choose to use the methods of design and carving, described in this book, you take these risks youself, otherwise, please do not use them!!

How I make propellers.

AFTERTHOUGHTS.

It seems incorrect to me that a book (?) such as this should end with such a negative thought as the one at the bottom of the previous page, especially after one has gone to all this trouble to write it, and you have gone to all the trouble to read it. There just ought to be something more encouraging to leave with you.

There is too. It is this. There are quite a number of books dealing with the designing and carving of wood propellers on the market at the present time. They are generally much less long-winded than this one has turned out to be. A few of them are very elementary. Several are written by real educated engineers with real degrees behind their names. A few present designs which I would consider definitely archaic. I have about 6 or 8 books that I have acquired (by purchase) during the years. Besides these there have been , since I have been a member of EAA, quite a number of articles in SPORT AVIATION (beside the ones I have mentioned earlier,) dealing with various aspects of the subject. Some of these I think have been good and some others have been,(in my opinion,)little more than space fillers, even though the writer may have been considered to be an "authority". I would recommend that you would read them all, and draw your own conclusions. Be always on the lookout for these books and and articles. Especially if you are seriously interested in the art. There are a number of books on the subject advertised in SPORT AVIATION from time to time.

One other thing I would advise; whenever you walk by a plane with a wood propeller, stop and take a good look at it. Notice the shape and the way the blades meet the hub etc. And when you are reading a man's book or listening to him talk, don't take everything he says without a questioning thought. He might be an "expert" and a famous one too, but he just "could" be mistaken. I could too.

Fixed pitch wood propellers are not obsolete any more than fixed pitch propellers on boats and ships are. Their design and construction is an art, even though some think of it only as a science. To me it is a very intriguing one too. So long.

----, Son, there is something else to watch out for.----, -There is no end to the writing of books, and too much study will wear you out.
(ECCLESIASTES Ch 12 vs 12)

Conclusion

Every book must end somewhere, even this one. There are many facets of this art of propeller making which could have been dealt with more adequately,or even perhaps endlessly, but I have already spent a great deal more work on it than I had origonally intended. It has also been a lot more difficult than I had anticipated. Maybe that is a good thing after all. How many things have there been that we would never have begun, and because of that, would never have accomplished, had we known how difficult they were to be.

My hope then, is that this book may give amateur propeller hacker outers some new insights into the art. I would also like to convince them that the designing and carving of wood propellers need not be the exclusive reserve of the man with the degree in engineering, especially for propellers intended for use on the smaller engines.

More of the designs which I have carved might have been included but the book is already too long, so these will have to suffice,--. - At least for the present. Maybe some time I will write an addenda.

Yours,

E. Alvin Schubert EAA no. 3408
Author