Flapper Facts

Newsletter of the Ornithopter Modelers' Society

Issue #6 Spring 1994

OMS News

Before you begin reading this exciting issue of Flapper Facts, please take a moment to look at your mailing label. If an "x6" appears in the upper right corner, it is time to renew your membership. If a larger number appears, you are OK.

Dues are $9 per year in the US and $14 per year elsewhere. Checks or money orders must be written out to "Nathan Chronister," 3140 Rt 209 #2A, Kingston, NY 12401.

Rules Change

In response to the suggestions of several members, the rules of the 1994 Postal Contest have been changed to encourage greater participation. The requirements for documentation have been relaxed, and a separate prize is now available for those who wish to submit unproven designs. I hope that many of you will take advantage of this opportunity and send in your ideas on how one might build a variable-span ornithopter. You will find in this issue an article on variable-span flapping in birds and bats.

Indoor Flying Models

OMS member Lew Gitlow of Indoor Model Supply tells me that his new book, Indoor Flying Models, is approx. 160 pages, 8.5 x 11", with "loads of plans." Many of the plans are full size and include IMS kits in addition to the original designs of famous contest winners like banks, Coslick, Brown, Hunt, and dozens of others. The scope covers gliders to the F1D international microfilm class models. With all the illustrations, technical data, building and experimenting with his own models, it comprises years of work.

You will find a development that starts with a theme of man's first dream of flying and how with imagination and the use of experimental models he actualized this dream. Then with a strong message for instructors he presents material that can be used to stimulate interest before the instructor adds his own experience. The basics of tools, materials, and "the right moves" lead you from the most simple to the most complex models and techniques, including "How to brew your own microfilm solution," and the secrets of the experts are revealed including "What your best flying buddy won't tell you."

More details of the scope and content will follow during the year, but if you want to get your copy and be ready for flying with the latest info send $25 to Indoor Model Supply, Box 5311, Salem, OR 97304. Lew asks that you write rather than phone; Visa and Master Charge accepted, and quantity prices are available.

How to get John White Plans and Aeromodeller in the US

In the last issue, I published a reprint article from the British magazine Aeromodeller featuring John White's biplane ornithopter. I now know where you can get Aeromodeller and other British model magazines in the US. You can also get a plans catalog which will allow you to order Aeromodeller plans. Please write to Wise Owl Worldwide Publications, 4314 West 238th Street, Torrance, CA 90505-4509, and ask for their extensive list of publications.

New Record

Roy White has been flying his ornithopters under Cat. I ceilings a lot lately, and he has the record up to 6:58, as of 20 Feb. 1994.

Ornithopters in Schools

I don't know if there are any

teachers in the OMS, but a recent letter from Mike Palrang made an interesting suggestion. Mike flew a high-performance indoor design for his daughter's 4th grade class, and says the kids and teacher really enjoyed it. Ornithopters are fascinating and would help get children interested in science if used in this way. They also offer a unique opportunity to demystify biology and show that it behaves according to physical laws.

Eccentric

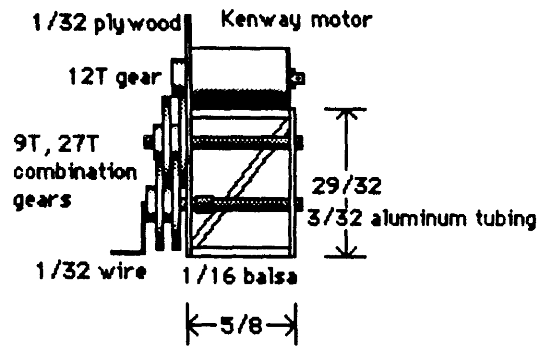
Roy Clough has contributed some of the plans to this issue of the newsletter. He also sent me a model of the eccentric-driven flapper. I couldn't get it to perform very well, but it did achieve an extended glide. The limit on performance seemed to be that as the rubber band was wound tighter, the whole model curled up, pointing the wings up instead of laterally. If you wish to try this unique and very simple type of model, make sure it is stiff enough to avoid this problem. Possibly use a balsa motor stick along the leading edge of each wing to spin the goose neck. Roy encourages you to try various neck weights, lengths, etc.

Micro Electric Gearbox

Although my brief attempt at building a micro electric ornithopter failed, I decided to publish the gearbox design in case it has any potential. An important thing to keep in mind is that the power/weight ratio of the micro flight system is very low. I tried to compensate by using a lot more gear reduction and a much lighter wing loading than has been previously successful. Maybe that was the wrong approach, or maybe the problem was with my tandem configuration. To build the gearbox, you will need a 12-tooth, 48-pitch gear from the little motors they sell at Radio Shack. The other gears are from the Hobby Lobby large motor geartrain, HLH731. The output crank is recessed into the final gear so it can't disengage. I attached the 12T gear to the small motor shaft by first plugging the hole with CA and baking soda, and then drilling a new hole. The gearbox works great...

Micro-electric ornithopter gearbox

Designed by
Nathan Chronister

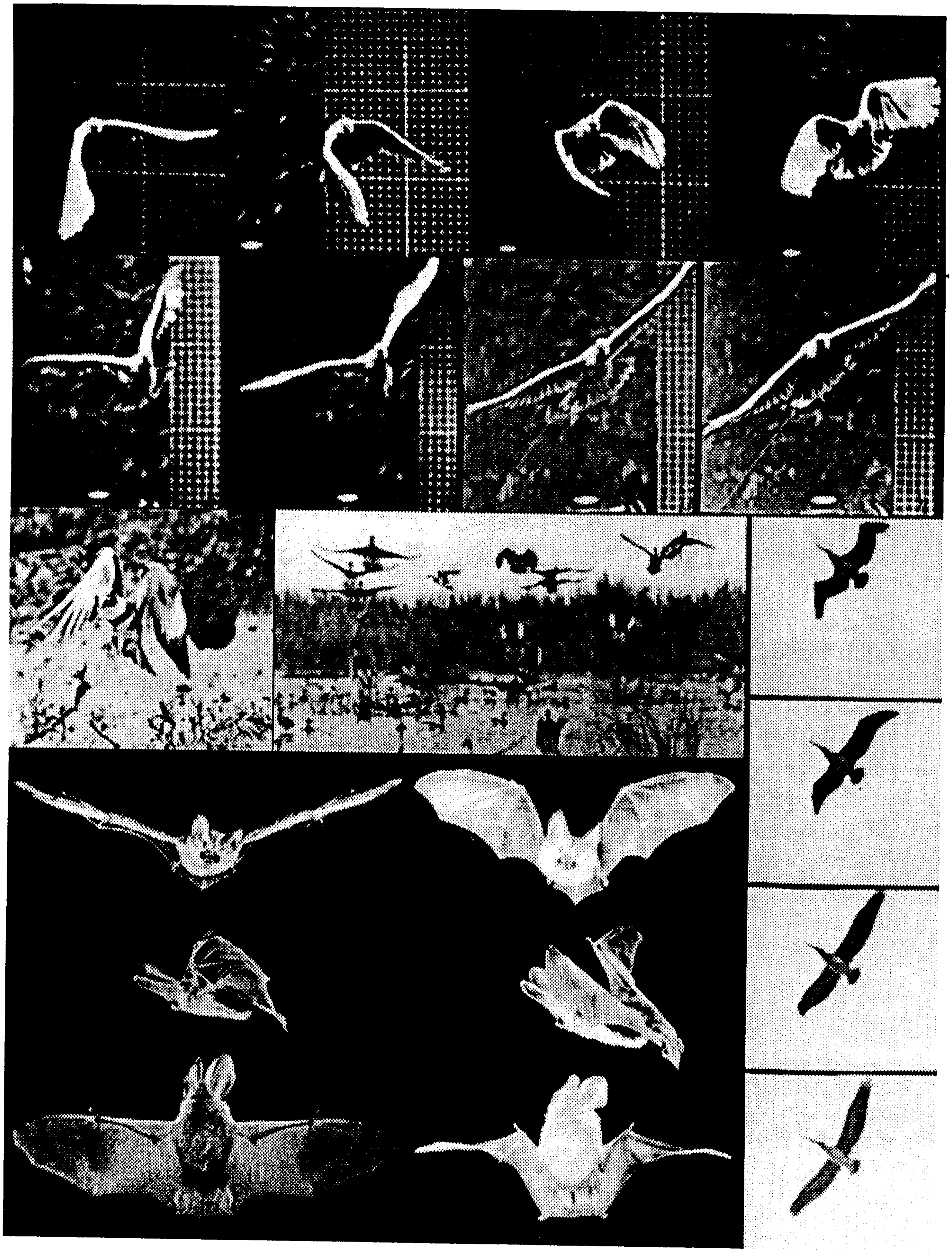


Variable-Span Flapping: What it is, and why it's important

Almost every ornithopter has used two fairly simple motions to produce flapping flight. Specifically, the wings move up and down, and they twist to provide different angles of incidence. Some people have assumed that birds fly the same way. But why should they fly that way, when they can use more efficient techniques?

First of all, the mass of the wing can be more easily raised through the recovery stroke if it is folded. This allows the wing to follow a straight line rather than an arc, saving time and energy.

Also, there are aerodynamic advantages to wing folding. During the downstroke, a wing produces lift and thrust. During the upstroke, however, things are a lot different. The wing can either produce a force which is down and forward, or one which is up and backward. Either way, it isn't very efficient. By decreasing the span and area of the wings during the upstroke, the upstroke can be gotten through more



VERTEBRATE FLIGHT
NORBERG, U.M.

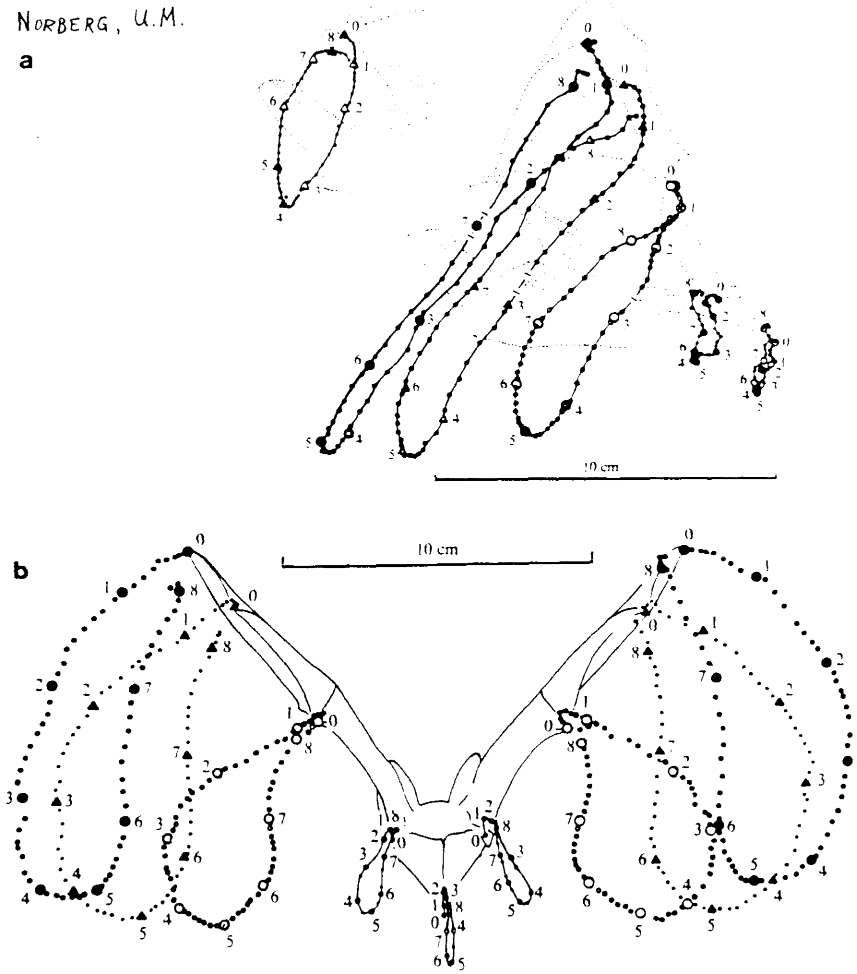


Fig. 9.2 *a* Lateral and *b* posterior projections of the tracks (traced relative to the body) of the tips of the thumb (only in *a*) and the third-fifth digits, feet, and tail over a complete wingstroke of the long-eared bat (*Plecotus auritus*) flying horizontally. The *numbers* indicate each 100th of a second starting from the uppermost position of the wings. In *a* the flight speed is 2.35 m s^{-1} and the stroke frequency is 11.9 Hz, and in *b* the speed is 2.4 m s^{-1} and the frequency 11.8 Hz. (Norberg 1976a, by courtesy of The Company of Biologists Ltd; from cine films run at 700-800 frames s^{-1})

quickly with less waste of energy.

If the upstroke provides lift, no energy is expended during the upstroke, but kinetic energy is lost which must be regained during the downstroke. With upstroke folding, the shorter path followed by the wing allows more efficient lift production (it behaves more like a fixed wing). With less loss of kinetic energy as a result, the downstroke power requirement is lower.

If, as in rubber-powered ornithopters, a downward force is produced by the upstroke, this force will be minimized by folding the wing. Some thrust will also be lost, but energy will be left unused which will produce both thrust and lift in the downstroke. A greater fraction of the total energy expenditure can be used in the highly efficient downstroke, so the total amount of power required for flight is lower. (If you can offer a more detailed or more correct model of this, please write it up in accessible terminology, and I will gladly put it in the newsletter.)

Birds are obviously capable of folding their wings, and from the above arguments they should be expected to do so. But someone will inevitably say, "I've been watching the pelicans (or gulls, etc.) and all they do is twist their wings." Pelicans fold their wings very little because they have a high aspect ratio. It is therefore advantageous to use a shallow flapping angle, and complete folding of the wings during a shallow upstroke would consume time and energy without great benefits.

The photo page for this article shows pelican movie frames in the lower right corner. The second frame can be identified as the top of the upstroke by the fact that the bird's left wing appears larger than its right. The left wing is more perpendicular to our line of sight due to the raised position of the wings. Measure both wings in the first frame and you will see that this is the middle of the upstroke. You can compare this to the bottom frame and see that the upstroke span is about 77% of the downstroke span.

Seen from below, up and down flapping alone can cause an illusion of span variation, but this procedure corrects for that. The changed shape of the wings also indicates folding.

The top of the page shows the complete cockatoo flapping cycle with a US span only 66% of the DS span. You can now see that the upstroke (3 frames) is faster than the downstroke (5 frames).

The duck and kingfisher seem to show even greater folding, but they have no downstroke pictures for exact comparison. The kingfisher (left center) shows gaps between its primary feathers, something which is common during the folded upstroke. This allows air to pass though the wing, enhancing the effects of span reduction.

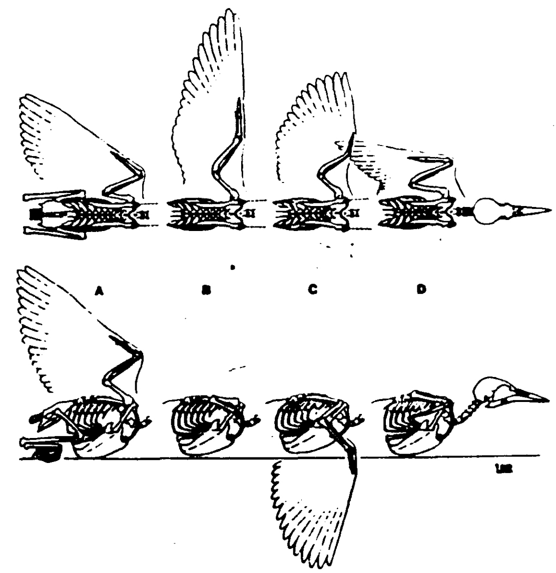
In slow flight, the wings move up-and-back and down-and-forward instead of up and down. Here, separation of primaries has another function. Twisting of individual feathers allows lift to be produced on the upstroke, while bats, insects, and hummingbirds have to twist the entire wing to accomplish this.

Many OMS members do not view ornithopters as an attempt to imitate wildlife, but the performance advantages of upstroke wing folding should be considered. There may be some increase in weight and friction with the added complexity of variable-span wings. But with further refinements, we will likely find, as natural selection has, that folding wings work best.

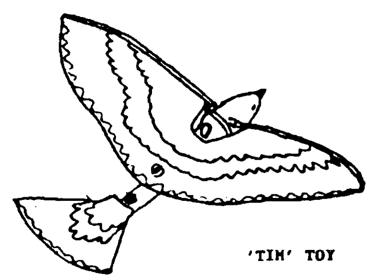
Photo credits:
Aymar, G. Bird Flight.
Muybridge, E. Muybridge's Complete Human and Animal Locomotion.
Norberg, U.M. Vertebrate Flight.

<u>Tim Bird Revisited</u>

The following article was provided by Peter Valentine. The Tim Bird toy ornithopter is available in many toy, kite, and science stores. It weighs 17.4 grams and flies for about 8 seconds. Pete's version flies for 20 seconds on the same motor, even though it weighs 30 grams.

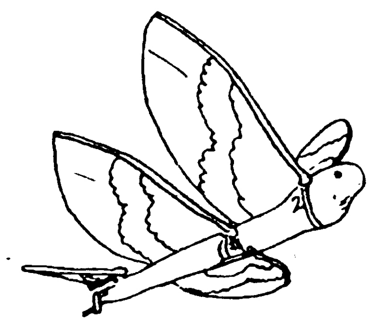


Phases in the wingbeat cycle of the European starling based on cineradiographic analysis
JENKINS, F.A. et al. SCIENCE vol. 241 p. 1496



'TIM' TOY

Patented U S 1969



VALENTINE 1985

MY EXPERIENCE WITH MECHANICAL DRAGONFLYS

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In 1985 I thought of combining parts of two 'TIM ' wind-up toys to imitate the dragonfly configuration of two closely spaced pairs of flapping wings in front of one another. It wasn't as simple as I imagined, but I eventually made a number of these flappers, got them to fly better than the original toy, and had some fun along the way. Perhaps others will find this interesting and want to try their hand at building mechanical dragonflys!

How to Build a Mechanical Dragonfly

Building a dragonfly from TIM ornithopters requires two toy kits plus one more crank mechanism and a fabricated drive shaft to connect the front and rear wing crank mechanisms as shown in Figure 1. Some sources used to sell 'replacement parts', which was handy, because three heads, two bodies, two wings, and one tail cost less than three ornithopters. Because these toys are made from thermoplastics (nylon and polyethylene?), I had poor luck trying to glue things together, but cutting and welding using a wood burner or soldering iron works well enough if care is taken not to burn the plastic and make it fragile.

Referring to Figure 2., peel the heads off two crank mechanisms after first cutting behind the hinges and on/off switch. Remove the hinges, connecting rods and on/off switch from one unit, and modify the crank by cutting off the pin and melting a hole where it used to be. Melt the other end of this crank to transform the hook to a rectangular tab (this will fit into the drive shaft slot). To complete the rear crank assembly, turn the modified unit around and mate it to an unmodified unit so that the pin of one crank fits through the hole that was made in the other, and join the two units permanently by welding scrap pieces of nylon to the rims of the two crank halves. This requires some dexterity to keep things lined up while soldering on the attachment structure!

Next, weld a body on to the rear, or hook end, of the frame of the crank assembly made above. Then weld a partial body to the front frame of the rear crank assembly after deciding what hinge separation is desired. In different models I used fore and aft hinge separations of 2" to 3.25" with success and didn't have too much trouble connecting the fore body to the front of the rear crank frame. Naturally, the front wing gets trimmed quite a bit, and I did that step last.

For the front crank mechanism, it seemed necessary to keep the snap on/snap off feature of the original bird head so that the drive shaft could be inserted/replaced, but I tried several head modifications. Usually I discarded the rubber bumper to save weight. Since the crank sometimes rubs against the inside of the head in the stock toy, I tried cutting away material in that area. This gave it a nice smile, but allowed dirt to get inside. The best solution was to weld the aft part of the head to the crank frame, cut off the front and rotate it upside down, and then melt it back on. The hook end of the front crank is melted to the same tab shape as the front end of the rear crank so that it will slide into the front end of the hollow drive shaft. I also eliminated the on/off lever from the front crank to avoid loading up the drive shaft.

The lightest drive shafts started as plastic report binders found at discount stores. They have a c-shaped cross section about .125" x .5" that is melted shut to fit the crank tabs, with the length being set by the fore and aft hinge spacing. Final fitting is done by inserting the shaft into the forebody onto the tab of the rear crank and then gently inserting the front crank tab into the other end of the drive shaft while 'snapping' the head on. At this point I would install a rubber motor and maybe a rear wing and make sure everything worked right without binding when I turned the wind-up crank. I gave the drive shaft a 45 to 75 degree twist, which I'll get into later.

Now mount the buttons that hold the trailing edge of the wings to the body and trim the wings. For the fore wing I cut the button and surrounding material out of the discarded portion of the front fuselage and attached it near the aft edge of the front fuselage. Then, with stock wings installed front and rear, I marked the front wing for trimming so that it would clear the rear wing and also marked where to put the hole and hole reinforcement. The wings shouldn't bind up on the downstroke or get too slack on the upstroke. I sometimes narrowed the rear wings for appearance sake.

Test Flying the Mechanical Dragonfly

With an untwisted drive shaft, I had a choice when mounting the head of the dragonfly to the shaft of whether all four wings went up and down in unison, or, with the drive rotated 180 degrees, one set went down while the other went up. I tried it both ways. With the wings going in unison, the thing flew like an anemic moth with lots of up and down body motion. With the wings going in opposite directions, it ran much smoother mechanically, but it still didn't fly as well as the original toy. This was puzzling because I had read in one source (Ref 3, p. 56) that dragonflys flap their wings 'exactly' opposite one another, and I thought this would be the best way.

Now this was the middle of June, 1985, and it just so happened that while I was thinking about what to do next, an article appeared in Science magazine by researchers who had been performing tests on living dragonflys (Ref. 2). They presented a chart of wing motion that showed that the insect flapped with the rear wings starting down about a quarter cycle ahead of the front wings. When I made a twisted drive shaft that made the rear wings lead by about 90 degrees and put it into the prototype, it flew as well or better than the original toy. That was more like it!

When I researched dragonfly wing motions, I found that the 90 degree, rear wings ahead, phase relationship had been previously reported by Chadwick (Ref. 1) in 1940 and that a similar plot was produced by bi-winged locusts in 1956 (Ref. 4). Chadwick's explanation was that this phase relationship is best because it allows the rear wings to stroke down without flying through dirty air from the front wings, but there may be more to it than that. For one thing, dragonflys can vary the phasing to suit their needs. Reference 2 says that they saw the rear wings lead from '50 to 100 degrees'. In fact, in a recent Scientific American Frontier progam on Public TV, I saw a slow motion film of a dragonfly rising up and to the rear with all four wings flapping down at once. So it may turn out that the 90 degree phase angle is best for 'cruise' or maybe best just for 'high speed cruise'. No one knows what the insects were trying to do in the laboratory (except probably trying to get away). Another reason for having a particular phase relationship could be that the insect is trying to get the best performance out of the unsteady effects (like 'vortex shedding') that occur when the wings change direction and also when they interact with each other aerodynamically. From the articles I have read, the authorities seem to say that the high lift that dragonflys and other insects create cannot be explained by applying steady state aerodynamics. Therefore 'unsteady' effects are the answer. Nobody wants to repeat the statement that 'bumblebees can't fly'!

I should mention that the mechanical dragonfly produces a strong 'nose down' moment that has to be countered with the tail deflected upwards. One of the last modifications I tried was to extend the tail by splicing on extra body material. This gives the tail more leverage and also adds a 'nose up' moment from the weight, and both these factors allow a reduction in the size of the horizontal stabilizer. This requires replacing the TIM supplied rubber motors with something homemade and longer, and I never made any progress with this. I also never tried a vertical stabilizer, but this might make for straighter and less exciting flights, which would be useful if someone was trying to do a side-by-side comparison of the effects of wing spacing and size or driveline phase angle.

Another thing worth mentioning is that the TIM mechanical dragonfly will sometimes fly in a stable fashion with a 'nose-high' attitude of 30 to 45 degrees. Its not clear whether this is much different than real dragonflys or not because several researchers have measured the insects 'stroke plane' as having a tilt with respect to the body of about 30 degrees with the wings sweeping forward going down and rearward going up. This would be the equivalent of tilting each hinge 30 degrees 'nose-up' on the TIM model, but this is not feasible in this design due to the need for universal joints at the rubber motor and drive shaft. It's not clear to me whether dragonflys have wings with simple hinges or with ball joints. Several references seem to say that the dragonfly uses muscles to actively steepen or flatten the wings during the wingstroke. This would surely imply both a pitching and a flapping freedom of motion in the wing joint, and this would be accomplished most simply with a ball joint.

How to Get Rid of Mechanical Dragonflys

I've built and flown a half dozen or so TIM dragonflys and scrapped a few after hard impacts, but the loss of the first prototype is the most interesting.

In late June 1985, I flew south to visit the Pratt and Whitney GPD Plant in West Palm Beach where I was on temporary assignment. The Tim dragonfly had been flying well for a week and I brought it along. At lunch the next day I invited a few co-workers to witness a flight or two out by the helicopter pad between the parking lot and the big 'reflecting pond' that was dug to provide fill for the plant's construction. Apparently the helicopter pad had been replaced by a parking lot since I had last visited, so we ended up on the grass next to the cars. I therefore decided a short first flight would be best and only wound it up 10 or 20 turns. The flight was still pretty good as it circled around me and lined up for a nice touch down. Unfortunately, it started drifting off to the right and even though it was almost on the grass, the ground started sloping away towards the pond. You can guess that it finally touched down just out of reach in the water, where it floated and continued to flap feebly. We were just starting to think about getting a stick to fish it out with when someone noticed a small alligator swimming out from the bushes and headed straight towards it. As it got close, someone tossed a soda can at the gator to distract it, but this only startled the animal and it disappeared with a splash of its tail and the No. 1 prototype, which was never seen again.

References

1.) Chadwick, L.E., 'The Wing Motion of the Dragonfly', Bulletin of the Brooklyn Entomological Society, Vol XXXV, Oct. 1940, No. 4, pp. 109-112

2.) Luttges, Marvin and Somps, Chris, 'Dragonfly Flight: Novel Uses of Unsteady Separated Flows', Science, 14 June 1985, Vol. 228, pp. 1326-1329

3.) Nachtigall, Werner, Insects in Flight, George Allen & Unwin Ltd., London, 1974

4.) Weis-Fogh, T., "Biology and Physics of Locust Flight. II. Flight Performance of the Desert Locust (Schistocerca gregaria)", Phil. Trans. B 239: 459-510

FIGURE 1. PARTS REQUIRED FOR MECHANICAL DRAGONFLY

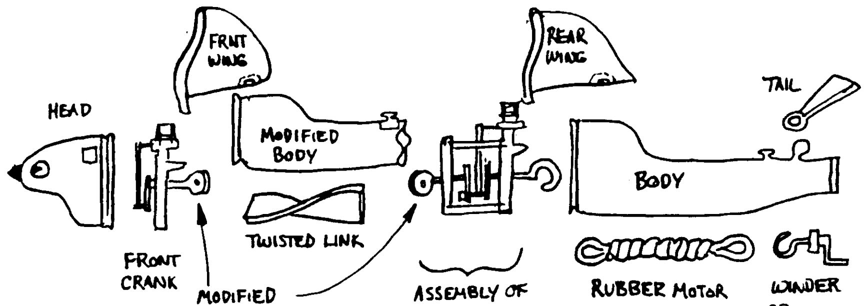
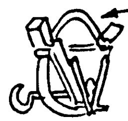


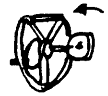
FIGURE 2. ASSEMBLY STEPS

a.) REMOVE SKIN FROM TWO HEADS TO EXPOSE TWO CRANK MECHANISMS

b.) REMOVE TOP ARC FROM BOTH MECHANISMS

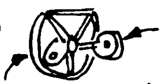


c.) REMOVE HINGES, CONNECTING RODS, AND ON/OFF SWITCH FROM ONE CRANK MECHANISM

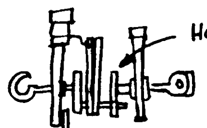


d.) MODIFY HOOK INTO TAB

CUT OFF CRANK PIN FROM c). MELT HOLE IN SAME LOCATION

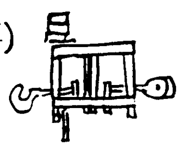


e.) HOLE MADE IN d.) FITS OVER CRANK PIN

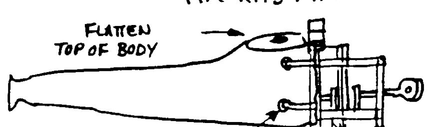


ASSEMBLE BACK TO BACK

f.) PERMANENTLY CONNECT USING NYLON SCRAPS SUCH AS DISCARDED CONNECTING RODS OR PIECES OF MOTOR TOOL THAT COMES WITH TIM KITS. HAVE FUN KEEPING IT LINED UP!



g.) ATTACH AFT BODY USING STRAPS MADE OF NYLON.

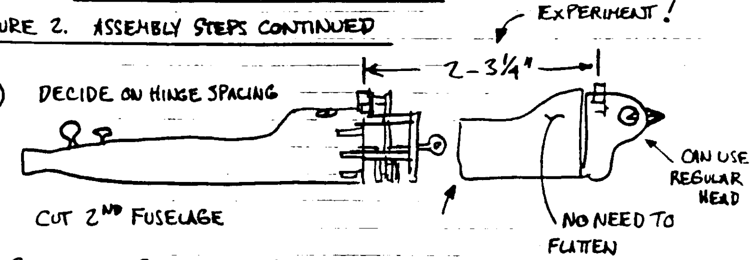


MELT NYLON THRU HOLE TO MAKE SOLID CONNECTION

TIM MECHANICAL DRAGONFLY

FIGURE 2. ASSEMBLY STEPS CONTINUED

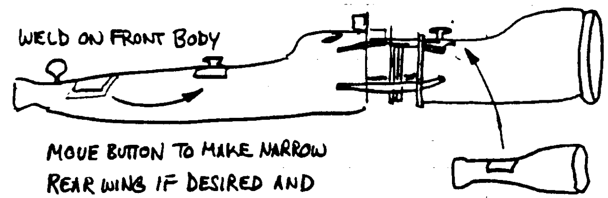
h.) DECIDE ON HINGE SPACING



CUT 2ND FUSELAGE

RECOMMEND REMOVING ON/OFF SWITCH FROM FRONT HEAD

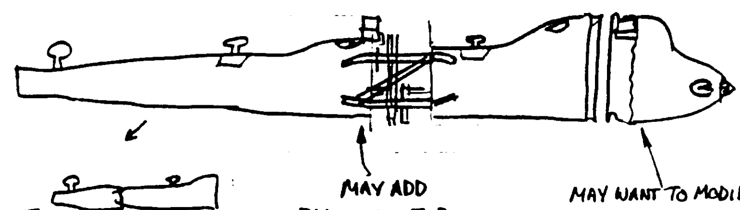
i.) WELD ON FRONT BODY



MOVE BUTTON TO MAKE NARROW REAR WING IF DESIRED AND PATCH HOLE

MOVE BUTTON FROM DISCARDED PART OF BODY

j.)

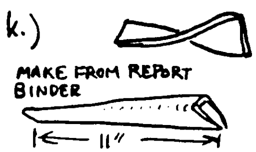


CAN SPLICE ON BODY EXTENSION AND USE LONGER MOTOR!

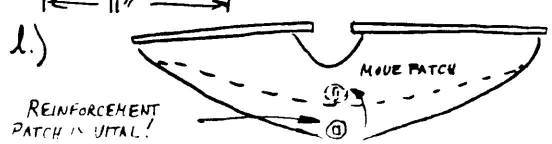
MAY ADD DIAGONALS FOR STRENGTH

MAY WANT TO MODIFY HEAD TO PREVENT CRANK RUBBING (COMMON IN TOY!)

k.) FABRICATE TWISTED LINK - RECOMMEND 45 TO 75 DEGREES. (SLOP IN LINKAGE WILL INCREASE LAG ANGLE TO ~90°)



l.) TRIM WINGS AFTER MARKING ON DRAGONFLY.



Joss Levy CO2-powered Ornithopter

12A Albert Mansion
Luxborough Street
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tel. 071 486 2312
29 January 1994

Mr Nathan Chronister
3140 Rt 209 #2A
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Dear Nathan

Thank you for your letter, and for sending me Flapper Facts which I read with great interest; I wish I'd known of your society years ago. I am now able to send details and pictures of my CO_2-powered ornithopter, having completed it in late December and flown it with some success on all nine days of the London Model Engineer Exhibition.

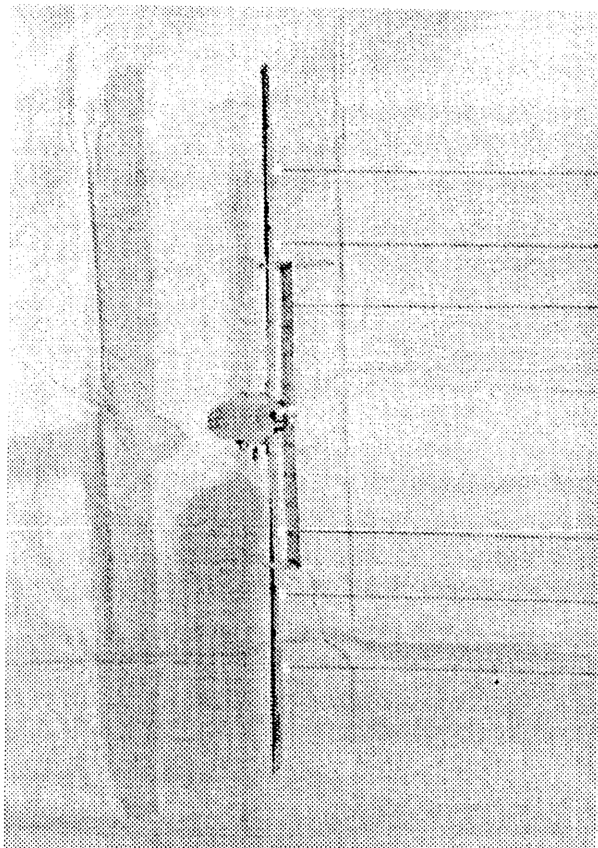
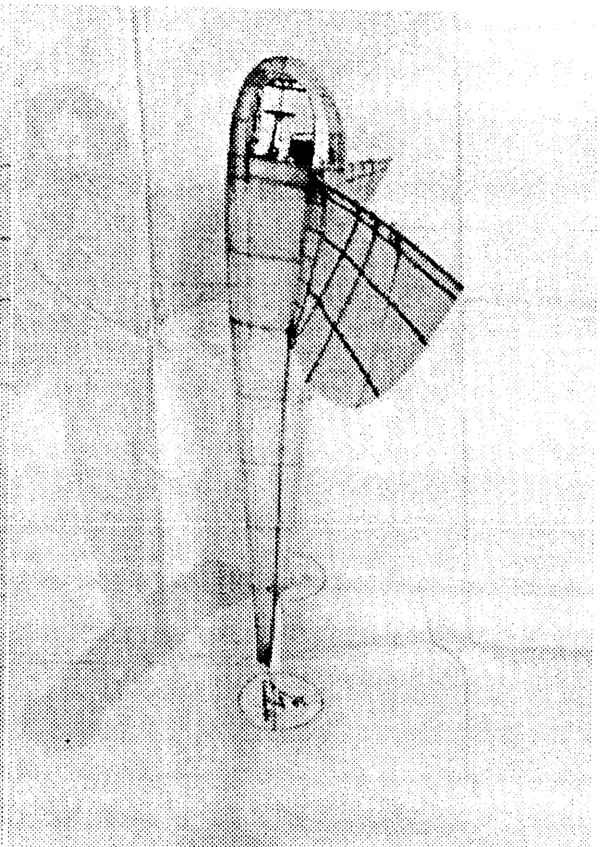
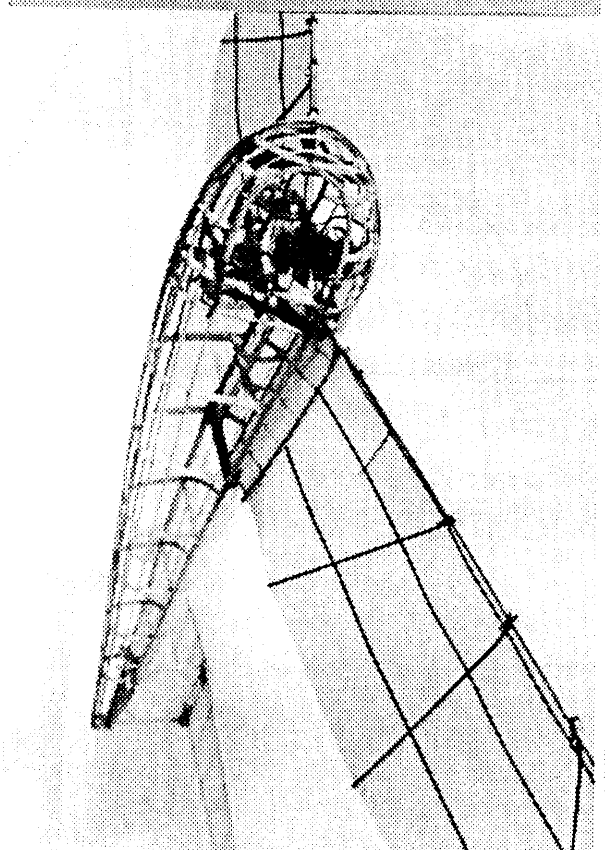
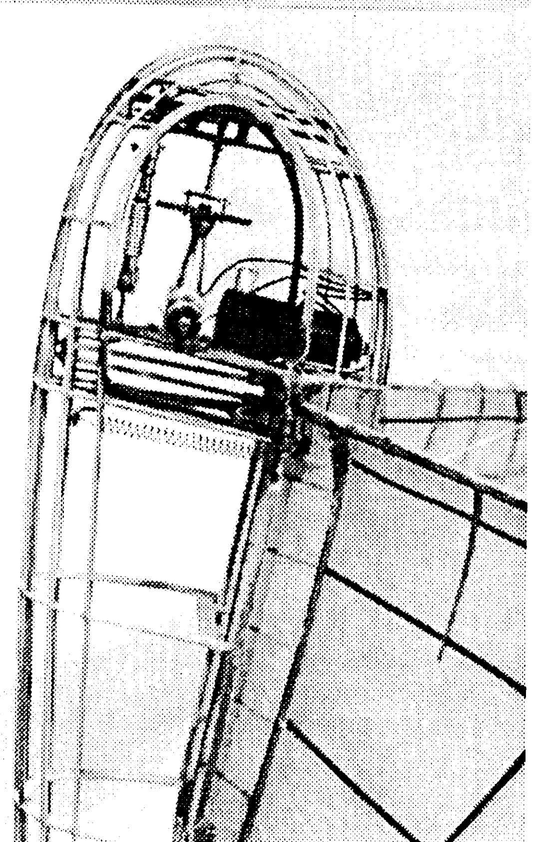
The motor is a twin cylinder Gasparin GM120T (0.24 cc). I have used a clock gear as a flywheel; the gear teeth are helpful for providing a good grip for starting the motor. A coupling on the flywheel takes the drive to a two stage gear train (more clock gears) giving a 17½:1 overall ratio (2 flaps/sec. at 2100 rpm).

The output of the gear train winds up a spring (actually a tension spring, but misused in this particular application in that it only takes torsional loads). The spring turns the crank which operates the wings via a pair of connecting rods. The purpose of this spring is to accommodate the fluctuation in the crank's angular speed over the flapping cycle, thus reducing the tendency for the motor's speed to vary over a 17½ revolution cycle. In other words, it gives (nearly) constant torque at the crank and constant speed at the motor.

The crank is also spring loaded by means of a tension spring (used properly this time) with a force sufficient to counterbalance approx. 70-80% of the wings' aerodynamic moments about their hinge lines. This small deficiency in the counterbalance ensures that the wings stop in the up position for the glide and also allows smoother running before the model is launched (i.e. before the wings start lifting).

The con. rods are arranged one behind the other on the crank (rather than having a "knife & fork" arrangement which would have allowed both rods to lie on the same plane). This requires therefore that one of the wing spars is swept forward inboard of the hinge line, and that the other is swept back. This arrangement gives three advantages: one is that the con. rods can be perfectly straight, carrying only axial loads, and can therefore be lighter than bent "knife & fork" rods; another advantage is that the fuselage can be made narrower by allowing the wing spar extensions (flapper arms) to extend more than half way across the fuselage, e.g. in this case the distance between the two wing hinge lines is 2" and the length of each flapper arm (measured from hinge line to con. rod "small end") is 1 1/16"; this small overlap of flapper arms gives the third advantage - very nearly symmetrical flapping motion of the two wings. Other "vital statistics" are:

length of con. rods: 2"

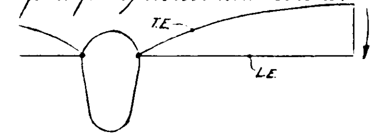





vertical height from crank centre to hinge lines: 2"
crank radius: 1/2"

This gives a flapping amplitude of 56°. The fuselage cross section was chosen to fit neatly around this arrangement.

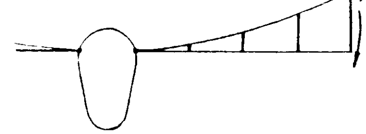
Turning now to the aerodynamics, I wanted to avoid having the usual loose-flap-of-paper style of wing since this gives a large amount of washout which cannot be efficient. To overcome this problem, I used three ribs (in addition to the root rib) to support the membrane on each wing. These ribs are attached rigidly to the spar. When the model is at rest, the ribs droop down at the rear (i.e. giving washin); but in gliding flight the aerodynamic lift raises the membrane and its ribs to a zero washin/out position, the spar acting as a torsion bar spring for the ribs. The ribs are not glued directly to the spar, but via steel brackets which can be bent for adjustment. The adjustment was carried out by simulating the aerodynamic lift loading on the wings in gliding flight by suspending the model from a ceiling using elastic threads (shirring elastic) attached to the wings at several spanwise stations along the 35% chord line (roughly where the centre of pressure could be expected to lie). The elastics were of equal lengths to ensure equal tensions. The flywheel was turned until the wings assumed a horizontal position and then the wings were checked for washin/out, and the brackets adjusted as necessary. One of the photographs shows this lift loading simulation, and the wings can be seen to have some washout which was later adjusted out.

I chose to use the radiating pattern of ribs for the reason that follows. Treating each wing as an airscrew blade whose direction of rotation changes periodically, it is clear that each wing must twist as an airscrew blade, ideally with true helical pitch. I believe my choice of rib positioning results in a good approximation to helical pitch. This is easier to explain with the aid of diagrams. Imagine a rear view of an ornithopter wing of constant chord (rectangular planform) on its downstroke:



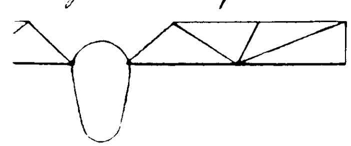
True helical pitch — large spanwise rate of twist at wingroot, decreasing gradually to a smaller rate at the tip

Now imagine that the wings have parallel ribs as on a conventional aeroplane. The rear view would appear thus:



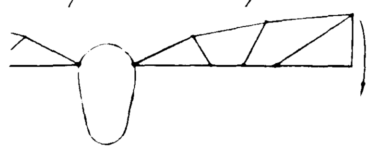
Small rate of twist at root increasing gradually to a large rate of twist at the tip. This is not satisfactory. (N.B. twist variation shown is for a wing with a conventionally tapered spar)

At the other extreme, imgine now that the ribs radiate out from the same point on the L.E. These ribs, being joined together at the L.E., must undergo identical deflections. The rear view now appears thus:



The rate of twist is large at the root until the tip of the first rib is reached. From then on, the rate of twist is zero.

It should be clear now that a reasonable solution can be obtained by using a compromise between parallel and radiating ribs, i.e.



This arrangement gives a fair approximation to helical pitch and has the additional beneficial property of allowing the wing tip to adopt negative camber (outboard of the third rib) on the upstroke.

It is inevitable that the fuselage will rise and fall in flight with each flapping cycle, and therefore each wing will have an "aerodynamic hinge line" lying outboard of the actual mechanical hinge line. I have attempted to allow for this by using a rigid trailing edge that extends for 1/2" past the wing's mechanical hinge line. From this point on, the wing can twist, but inboard of this point the wing is rigid. Each wing extends 1/2" inboard of the mechanical hinge line, into the fuselage, so that there is no gap between wing and fuselage to spoil the aerodynamic efficiency by allowing a vortex to form.

The wing spars are slightly arched from root to tip to compensate for the lift loading tending to flex them up. I think the use of arched spars would be of even more benefit on wings not fitted with ribs since this would allow the membrane to deflect more on the upstroke (when the curvature is greater) than on the downstroke (when the spars are straighter), giving a similar effect to the bird flight principle of the partial folding of wings on the upstroke.

Moving now from the theory to the flying, I took the completed, but untested, model to the Model Engineer Exhibition on the first of the nine days of this event, a hall having been set aside for the flying of models, and the rest of the building being used for trade stands and static displays. When I arrived, I was pleasantly surprised to find John White there with five of his biplane ornithopter models and a replica 1907 Clarke model aeroplane; he is the only ornithopter modeller I have ever encountered, so I was extremely pleased to meet him.

Although worried about looking foolish in front of a hundred people, I proceeded with the test flights and was rewarded with some quite decent flights. The only problem with the trim was a tendency to dive under power and stall on the glide, so I adjusted the trim for powered flight and just tolerated the stalling glide for the next couple of days before deciding to do something about it. Not being able to adjust the thrust line as you would with an aeroplane model, I moved the centre of drag instead by raising the tailplane 2" higher, using an extra fin to give a "T" tail configuration. This proved quite effective, with only a hint of a stall on the glide remaining and which I can live with. No doubt another 1/2" on the tailplane height would solve the problem completely.

The manufacturer of the CO_2 motor states on his literature that the motor weighs 18g complete with tank, and is suitable for models up to 30" span and 120g total weight. My model weighs 70g (2.5oz) and is 31" span (& 20" long). That difference in weight, I thought, would certainly be sufficient to compensate for the inevitable inefficiencies of wings and transmission compared with the typical aeroplane model. In fact the model flies very nicely, but only for about half a minute before the CO_2 runs out. I would expect it to run for a full minute with the standard tank which I've been using. I tried measuring the flapping frequency during flight, and this turned out to be about three flapping cycles/second, which is some 50% higher than I had expected. This meant that the motor too was running faster than intended (over 3000 rpm) and, with CO_2 motors, efficiency falls off rapidly as r.p.m. rises.

While it is possible that the gearing in the transmission is too low, I suspect that this is not the case. Instead, I believe that I have made the wing spars too flexible in torsion, resulting in the wings twisting too easily. The effect is just like having an aeroplane fitted with an excessively fine pitch airscrew. I will probably try stiffening the spars, although it is quite a big job to do properly, so I don't know when I'll get round to doing it. Larger tanks are available and I'm sure the model can manage the extra weight, but I'm reluctant to fit one until I've optimised the efficiency with the stiffened wings and rechecked the performance.

The hall where the flying took place was surrounded by a balcony supported on pillars which my model was forever flying into, so by the end of the nine days all the stringers (balsa) in the lower half of the fuselage were broken, and I have now replaced them with new bamboo stringers. The balsa stringers in the upper half of the fuselage were undamaged as were the two main balsa longerons. The nose section, from the crank position forwards, is made from bamboo which withstood all the head-on collisions with only minor damage. I hadn't fully realised before just how excellent bamboo is for small models. I had intended to use spruce, but when planing down strips to small sections I kept finding places where the grain wandered off at 45°. Bamboo is about the same density, the grain is dead straight; it is very resilient, and can also be formed into tight curves. I made each wing rib using a bamboo core with carbon fibre top & bottom, giving good rigidity from a rib only 3/64" sq., and the depth tapering off after the one third chord position. The root chord is 4·75".

The spars were made in a similar way using spruce, 3/32" sq. at the root with a straight taper to 1/32" deep × 3/64" wide at the tip, and carbon fibre material added top & bottom (0·015" thick at the root, tapering through 0·010" one third of the way out to 0·005" at the tip).

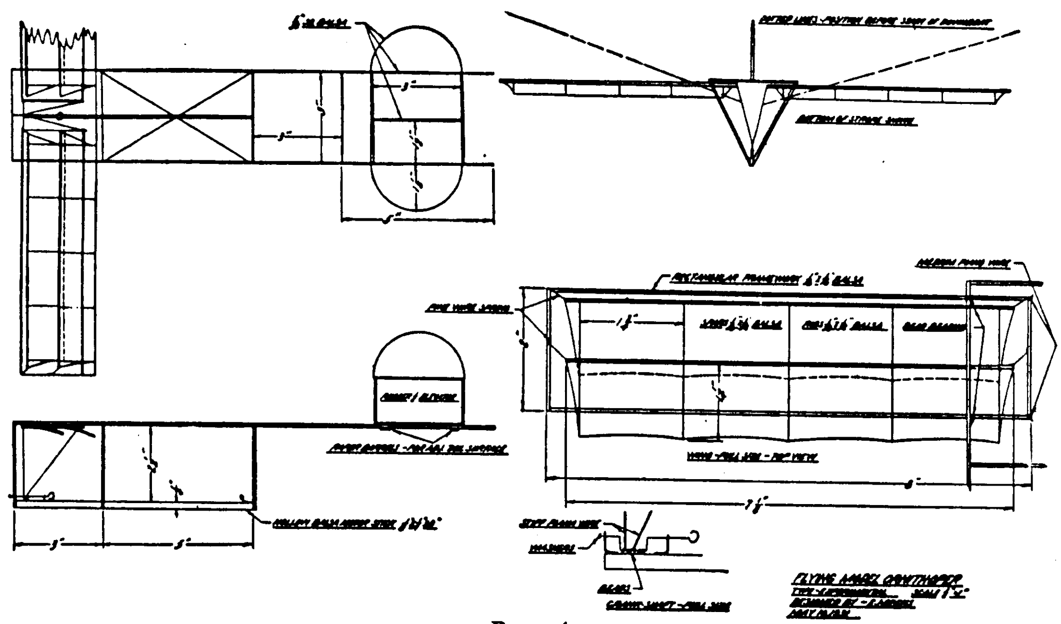
The wing membrane material is polyester tissue, which looks like light weight paper tissue but has much better resistance to tearing. I don't know if you have this material in the U.S.A, so I'm enclosing a sample and details of the supplier; it really must be the ideal material for this particular application.

polyester tissue, 20 g/m², white only ⟶ Available from:
manufactured by Klaus Salzer
I have found that a single coat of thinned banana oil is sufficient to seal it.

price £1·50/m² plus postage.
Mike Woodhouse's mail order list includes carbon fibre material in various forms, Mylar, Kevlar, and lots of other aero modelling materials & accessories.

M. J. Woodhouse
12 Marston Lane
Eaton
Norwich
Norfolk NR4 6LZ
U.K.

A NEW IDEA FROM THE PAST – 1931



PLAN 4

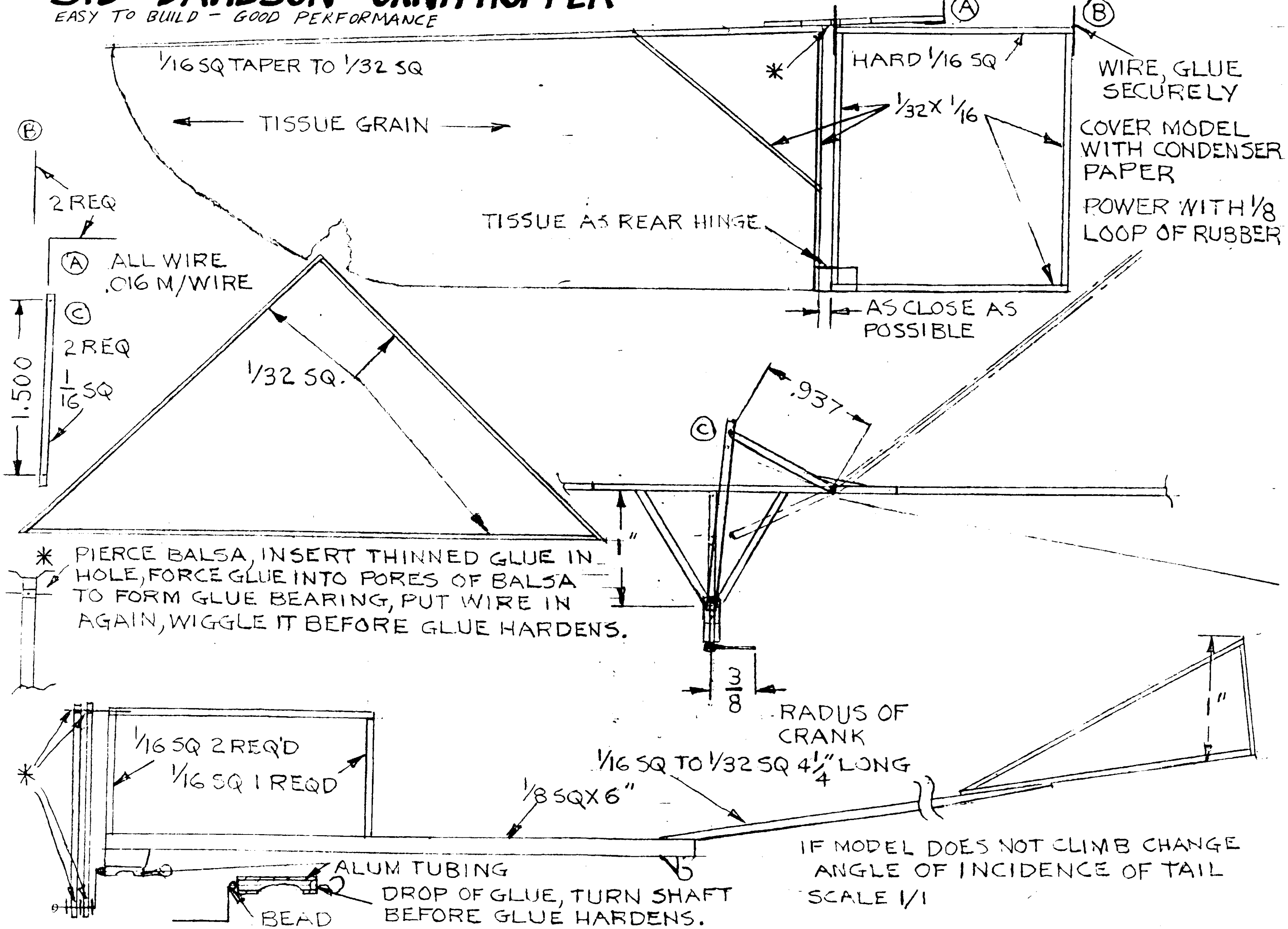
THIS wing flapper (Plan 4) is an instructive and amusing project; the model from which these plans were drawn was one of the most successful I ever built. In flight it makes a queer snapping noise caused by the unsupported trailing edges of the wing blades. On the down stroke the trailing edge of the forward blade is held in place by the second blade, which in turn is resisted by the supporting framework. As the wing goes up these edges bend down, and it is this which gives the model forward motion. The closed downbeat causes lift.

The construction of this model can be altered by the builder, but the dimensions should be kept the same. It is possible that you may have some kink that would aid flight. Note that the elevator and rudder slide back and forth on the rounded outriggers; this is accomplished by slides made by wrapping tissue around a one-sixteenth-inch nail, glued and let dry. When these are removed from the nail, they are glued to their respective positions on the empennage.

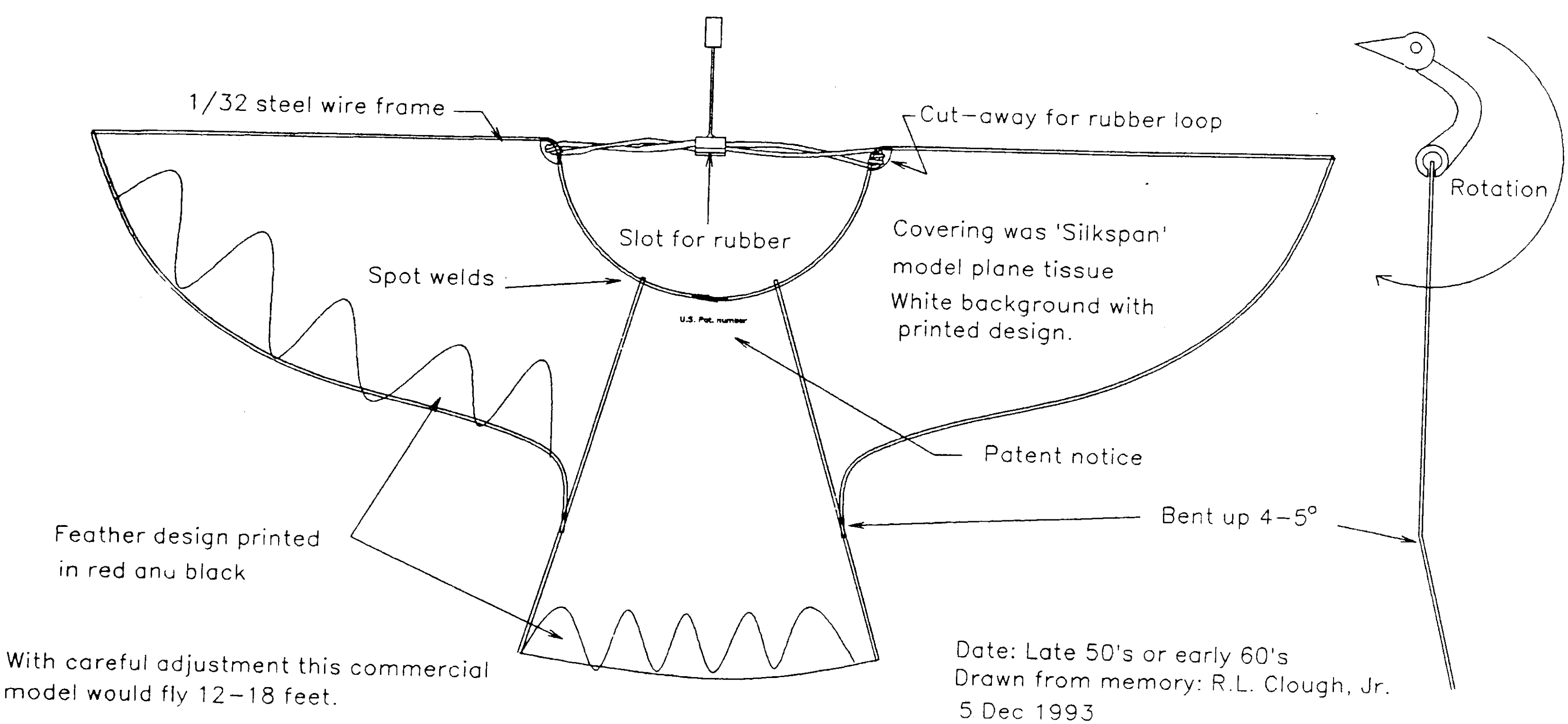
The model is wound and flown in the conventional manner; so wind her up and let 'er go!

SID DAVIDSON ORNITHOPTER

EASY TO BUILD – GOOD PERFORMANCE



ECCENTRIC DRIVEN FLAPPING BIRD

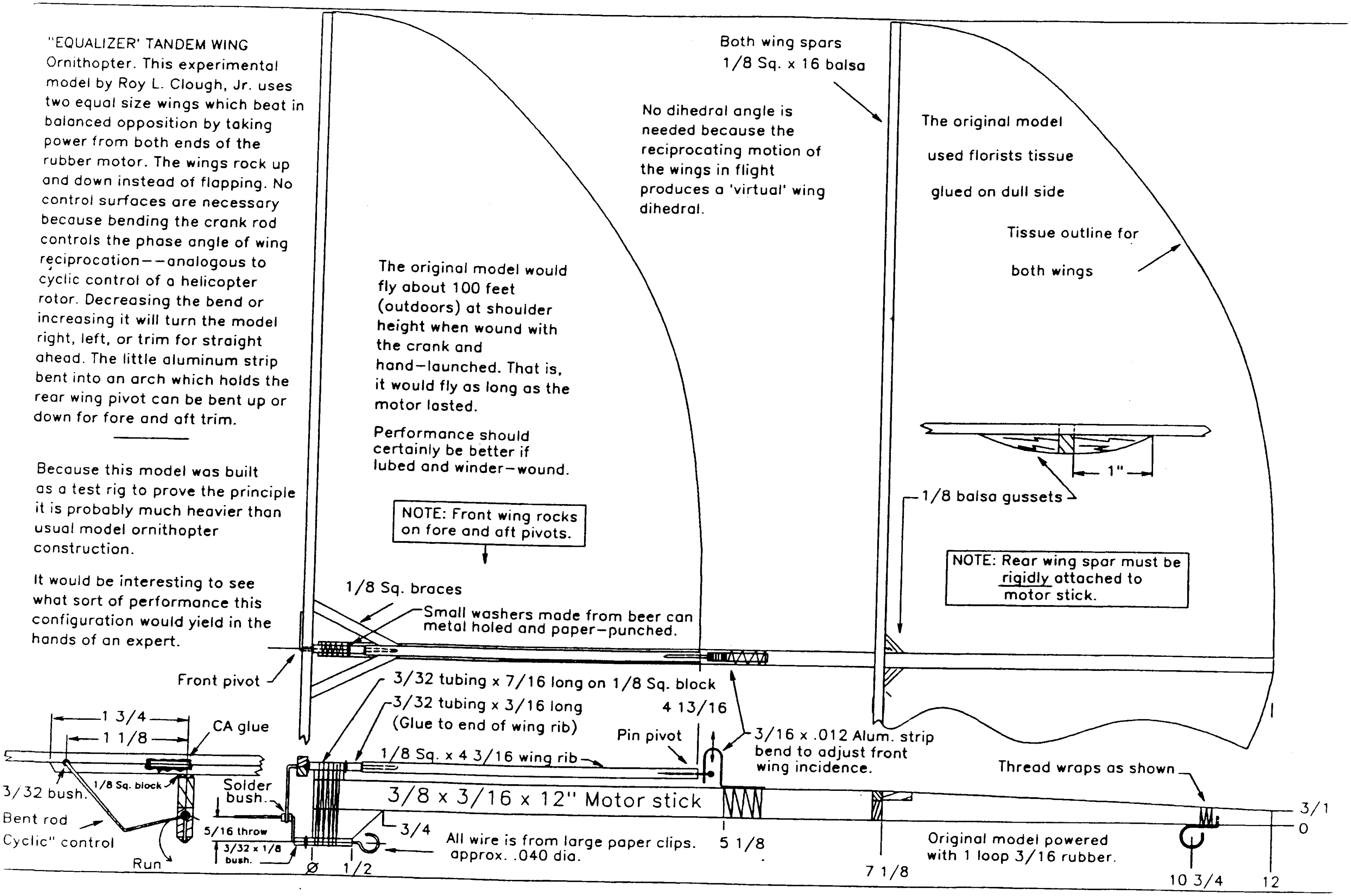


Date: Late 50's or early 60's
Drawn from memory: R.L. Clough, Jr.
5 Dec 1993

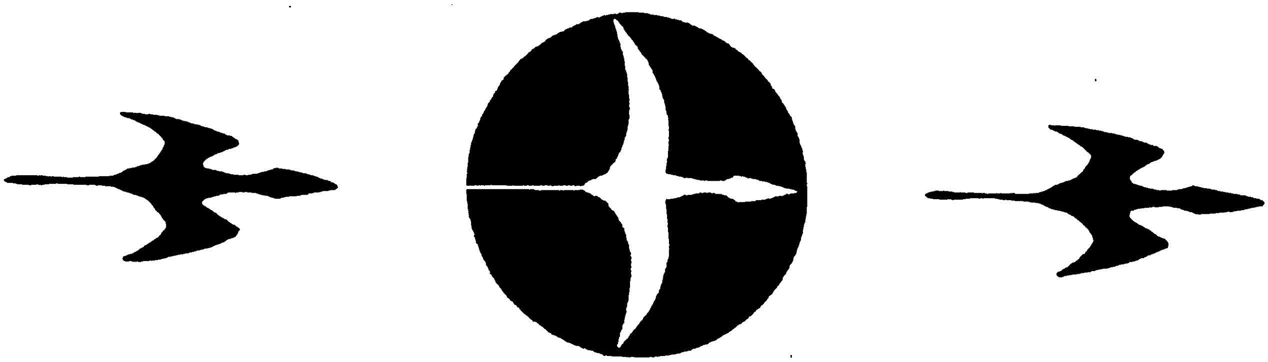
"EQUALIZER' TANDEM WING Ornithopter. This experimental model by Roy L. Clough, Jr. uses two equal size wings which beat in balanced opposition by taking power from both ends of the rubber motor. The wings rock up and down instead of flapping. No control surfaces are necessary because bending the crank rod controls the phase angle of wing reciprocation—–analogous to cyclic control of a helicopter rotor. Decreasing the bend or increasing it will turn the model right, left, or trim for straight ahead. The little aluminum strip bent into an arch which holds the rear wing pivot can be bent up or down for fore and aft trim.

Because this model was built as a test rig to prove the principle it is probably much heavier than usual model ornithopter construction.

It would be interesting to see what sort of performance this configuration would yield in the hands of an expert.



1994 Ornithopter Modelers' Society Postal Contest



Rules:

1. The purpose of this contest is to encourage the design and construction of ornithopters which partially fold their wings during the upstroke in an attempt to approach the appearance and efficiency of bird flight.
2. Anyone may enter. There is no entry fee.
3. Actual models or unproven designs may be entered. Entries in these two groups will be subject to different rules and will be eligible for different prizes.
4. Actual models will be given a score equal to flight duration x (mid-downstroke span - mid-upstroke span) / mid-downstroke span. Thus, both duration and span variation contribute to score. Other factors such as size and power source will not be considered.
5. Proof of duration may consist of a VHS videotape of a flight (non-returnable) or a statement signed by a contest director. Proof of span variation may consist of videotape or photographs (also non-returnable) of the model in front view. In either case, the model must be flapping its wings under full power while being held in place, and the wing tips must be clearly visible at the mid-downstroke and mid-upstroke positions. Also include a brief description of the model and its operation.
6. The entrant with the highest score will receive an autographed copy of Lew Gitlow's book, Indoor Flying Models, OMS membership for two years, and a copy of the Flapper Facts backissues since 1983. Second place will receive an autographed copy of Indoor Flying Models and OMS membership for one year.
7. To encourage broader participation, unproven designs may be entered. Designs must be clearly presented in 8.5 x 11" format with at least .25" margins, using one or two pages. All entries will be printed in Flapper Facts and the winner will be determined by member vote. The winner will receive an IMS Flapping Flyer kit, OMS membership for two years, and a copy of the backissues.
8. The contest will be administered by the Flapper Facts editor, who is not permitted to enter. Score determination and choice of winners is final. If fewer than two actual models are entered, prizes may be redistributed.
9. Entries must be received by March 31, 1995. Send all materials to Nathan Chronister, 3140 Rt 209 # 2A, Kingston, NY 12401.