Flapper Facts

Newsletter of the Ornithopter Modelers' Society

Issue #5 Winter 1994

Enter the 1994 Ornithopter Modelers' Society Postal Contest!

Win prizes, become famous, and make history by flying the first ornithopter ever to fold its wings on the upstroke!

This is an exciting time to be involved in ornithopter modeling. Recently, several gas and electric ornithopters have taken to the air, and OMS members have finally solved the problem of inefficient membrane wings by using semirigid structures. As for indoor ornithopters, progress came in the 1980's through a series of performance breakthroughs.

However, in the spectrum of ornithopter success stories, one accomplishment is curiously absent. No one (as far as I know) has ever flown an ornithopter with articulated wings, folding on the upstroke like the wings of many birds. Since birds are the ultimate inspiration for ornithopterous flight, it is appropriate for OMS to encourage this major forward step in ornithopter evolution. Even if articulated wings do not confer improved efficiency, the aesthetics of this flight mode will make our efforts worthwhile. Ornithopters in flight can look and move like real birds.

The motion of a bird's wing depends on the species. Large birds with high aspect ratios, such as gulls, don't fold their wings very much in flight. Nor do certain other birds such as hummingbirds and swifts. However, high-speed photography has revealed that many common birds fold their wings almost completely on every upstroke. If you have a window bird feeder, you can train your eye to see the folding of a house finch's wings in hovering flight. If you watch a jay or crow flying directly overhead, you can see a similar folding of the wings. The wings do not bend downward much at the wrist, as is commonly thought. They fold within a plane, decreasing the span.

It shouldn't be too hard to make an ornithopter which varies its wingspan in this manner. It is hoped that a number of people will be motivated by this contest to build one. Notice that the contest rules do not require the ornithopter to be as complex as a real bird. The problem should be much easier to solve if you devise the simplest possible method of span variation.

Prizes will be announced in the next issue of *Flapper Facts* . Some prizes will be covered by membership dues, but we are seeking prize donations as well, including cash, kits, supplies, or gift certificates.

Rules:

1. Anyone may enter.
2. There is no entry fee.
3. Entries will be judged based on a formula, so that duration and the amount of span variation determine score:

$$\text{Score} = \frac{Sd - Su}{Sd} \times d$$

Where Sd is the downstroke span, Su is the upstroke span, and d is the flight duration in seconds. Notice that without span variation, the score is zero.

4. Decisions are final.
5. Any ornithopter may be entered, regardless of size or power source. For simplicity, rubber power will be the most common. Outdoor models are allowed to benefit from air currents, but must be recovered intact. This allowance is intended to encourage larger models which would otherwise have shorter flights than indoor models. Preexisting models are allowed.
6. Entries must be received by March 31, 1995.
7. To enter, the following documentation must be submitted:

a. At least one clear photograph or negative.

b. An uninterrupted VHS videotape of one entire flight of the model. Ground or gentle hand launches are permitted. The videotape will be returned only if enough return postage is provided.

c. The video must also include a perpendicular top or bottom view of the model. In this scene, the model is to be held in its normal flight orientation with the wings flapping. This will allow the span variation to be measured from the TV screen, provided the flapping rate is not unusually high.

d. If you don't have a camcorder, borrow one. The extent of folding cannot be documented in any other way, since for some designs this quantity must be determined while the wings are flapping.

e. The following information must accompany the video: The entrant's name and address, the date and place of the flight, and a description of the model and its operation. Please include plans, although they are not required.

8. Any entries may be described and pictured in Flapper Facts and press releases unless the entrant requests otherwise when or before the video is submitted.

OMS information

I want to thank all of the OMS members who have contributed material to the newsletter recently. The next issue will be expanded to include all of the articles and plans I've received, and I'd like to see enough material for a thick newsletter every time. In this issue, we have some articles from *Aero Modeller* (May and June 1993), which editor John Stroud has generously allowed me to reprint. In these articles you will find information on ordering plans for one of John White's large outdoor ornithopters. As far as I know, these are the only plans now in print for a model of this size. You can subscribe to *Aero Modeller* by writing to them at:

Argus House, Boundary Way
Hemel Hempstead HP2 7ST
England

Time to renew your membership?

Under the new system, your mailing label indicates when your membership will expire. The number in the upper right corner denotes the last issue of *Flapper Facts* you will receive, if you do not renew. This is issue #5, so if "x5" appears on the label, your membership should be renewed as soon as possible to insure a continuation of services such as this newsletter.

How to join OMS

Ornithopter Modelers' Society membership dues, for new or renewing members, are $9 per year for U.S. residents, or $14 outside the U.S. due to higher mailing costs. If you send a check or money order, it must be made out to "Nathan Chronister," not to OMS.

OMS publications

Ornithopter Design Manual , by Frank Kieser.
42 pages, illustrated. $3.

Vast Ornithopter Information Directory .
7 pages. Self-addressed envelope and two unattached stamps.

Freebird . Plans for entry-level ornithopter.
11x17. SAE and two unattached stamps.

Carbon Fiber

One of our members is offering ten yards of carbon fiber tow for the very low price of one dollar plus SASE. I have used some of the sample he sent me, and I am very happy with it. It is much better than thread-wrap for reinforcing ornithopter structures, and about as easy to apply. The carbon fiber is available from:

Barry J. Berman
1375 N Broadway E-6
Escondido, CA 92026 USA

Barry writes: "The carbon fiber tow can be used to reinforce ornithopter structures. Strip to size. Wet. Pull between fingers. Use piece of sandwich bag to reduce friction. Thread can be made by twisting between moist fingers while under tension. Use slightly thinned Tightbond, RC-56, or slow setting epoxy.

"Wash hands before use to avoid transfer of skin oils.

"For ornithopters I think epoxy would be best. The fiber could be wrapped around joints to bind them. The fiber should first be saturated with epoxy.

"Spars would benefit with the application of a flat strand on one or more sides. If needed, a loosely spaced spiral could be added.

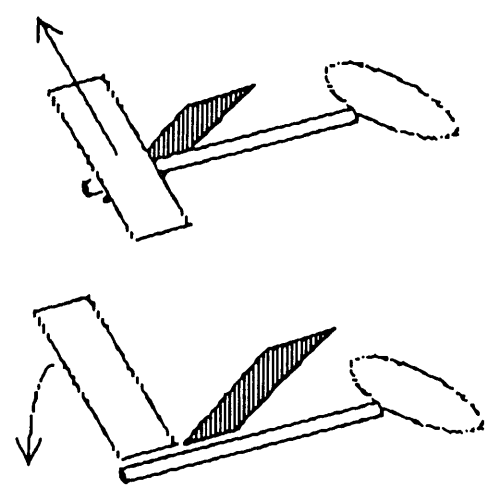
"Carbon fiber does not stretch. The twisted thread technique might [therefore] be useful for a trailing edge."

Flat strands are better than spiral wrap alone for wing spars. This is because spiral wrap does little to prevent bending. I think it is best to put carbon fiber on the top and bottom of the wing spar, but you might also put it along the leading edge to help prevent the wing from being bowed backward by membrane tension or broken in a crash. The great thing about the fiber Barry is selling is that you can separate the fibers to make a strand of any desired thickness or width.

Flapping without the upstroke

T. R. Quermann recently wrote to me with an interesting idea. He has proposed a design which bypasses the upstroke by sliding each wing diagonally, from the "down" position on one side of the ornithopter, to the "up" position on the opposite side. The air resistance would be less than for a normal upstroke, and there would be almost none of the downward aerodynamic force normally experienced. Since, when the wings are being raised, they cross the centerline of the model, the span is reduced to 50% of its original value, qualifying such a model for the postal contest. Actually, since the wings might remain at an oblique angle during the upward motion, the span reduction could be even less!

Unfortunately, this system would be very difficult to implement, and there are far easier ways of reducing the span on the upstroke, such as the use of a bending joint, in which case the outer portion of the wing slides across an inner panel. Quermann's technique might offer great efficiency, though, if the problems can be solved. Presently, neither he nor I have worked out how to do it. Semi-rigid wings would be required, since they must function regardless of which side the wing is on.



Next Issue

Easy-to-build and light: Plans by Sid Davidson.
Indoor plans and design ideas.
Joss Levy's new CO_2 powered ornithopter.

The Electric Dawn Project, part 1

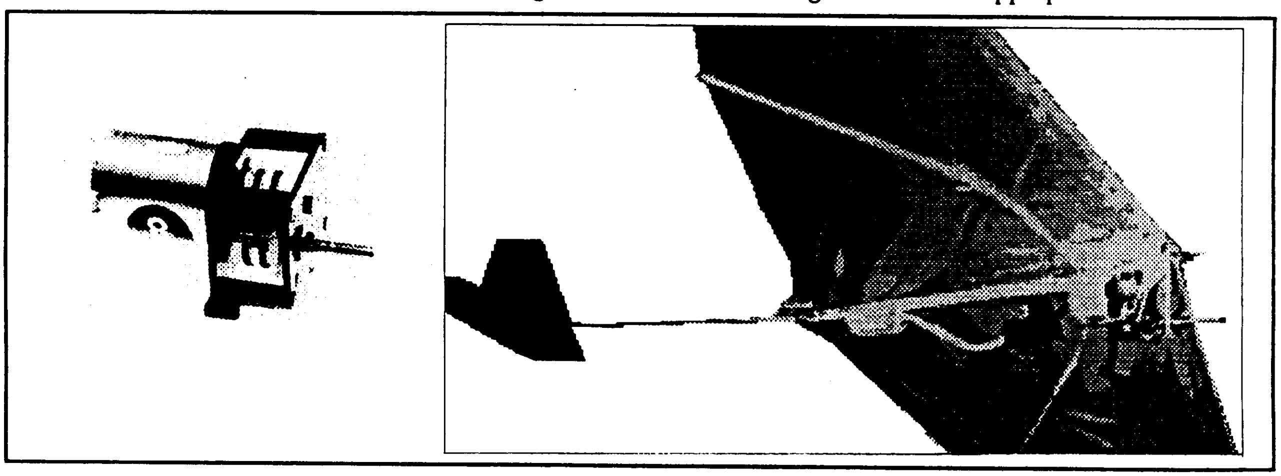
Tiny, delicate wings, snap-snap-snapping, propel the lightest of models into the protective indoor sky. To fly for any length of time, a rubber powered ornithopter must be very light, and it must be carefully constructed of the thinnest balsa with patience and precision. The power source, a twisted rubber band, is a convenient, yet not terribly compact, energy storage device. Rubber bands are capable of tremendous power output and high torque, allowing them to be used in ornithopters without gear reduction. However, the fact remains that their energy density is low. Rubber motors cannot provide the high power output required by large model aircraft, except very briefly and through the use of a huge mass of rubber. Large rubber-powered airplanes fly under power only for several seconds; they rely on gliding flight to stay in the air longer.

Until recently, ornithopters were almost invariably rubber powered. Some large models, over a meter in span, have flown successfully with this system. However, as size increases, rubber power becomes less effective and less practical. No one would think of using rubber bands in a manned aircraft, and that is one reason why P. H. Spencer, Jeremy Harris, and James DeLaurier built their ornithopters with gas engines. However, even those of us who aren't yet planning a full-scale wing-flapper could build larger, faster, longer-flying models if only we were no longer held fast by rubber bands.

The move to electric or gas power requires a quantum leap in complexity. The addition of a gearbox would be simple if suitable units were commercially available, but building one from scratch is not easy. With gas engines, the additional problems of starting and cooling an engine which is not simply attached to a propeller bring complexity to an even higher level. It is comparable to building an R/C helicopter without a kit, except that stresses are much higher on many components. In my attempt to build an ornithopter which others would be able to duplicate, I decided to use electric power so that the only additional complexity is that of the gearbox itself.

Electric flight systems are available which can easily out-perform rubber motors. Although I could not find any reliable information on how much power my ornithopter would need, certain information was available. I knew the power output and weight for a number of electric flight systems, and these figures were far superior to estimates for avian flight muscle. The only information I had on a real ornithopter suggested a power requirement of about 20 watts per kilogram for a Tim Bird rubber model. Perhaps that is too low to be accurate, but it was the only datum I had. I could easily match it with an electric ornithopter.

Using a VL Products (7871 Alabama Avenue, #16; Canoga Park, CA 91304 USA) M-25 motor, I would have almost 20 watts of power on three cells, and over 30 watts on four. The entire model would weigh only four ounces. To insure success, I used a lighter wing loading than Tim Bird's, and adopted the (supposedly more efficient) biplane configuration. Gear reduction was to be provided by a readily available gearbox, the HLH731 large motor geartrain (below) sold by Hobby Lobby (5614 Franklin Pike Circle; Brentwood, TN 37027 USA). The geartrain comes with its own 4 watt motor which was used in early test flights, December 1992. The model was stable, but it couldn't maintain altitude. With the much more powerful M-25 motor (3 cells), performance was somewhat better, but not good enough. I thought the reduction might be too great at 81:1, so I popped the front off of the gearbox and took out one of the gears. This is very easy to do. I also sawed off the upper pair of wings. I would have preferred a 40:1 reduction, but forced by the design of the gearbox to use a 27:1 ratio, I thought some reduction in wing area would be appropriate.



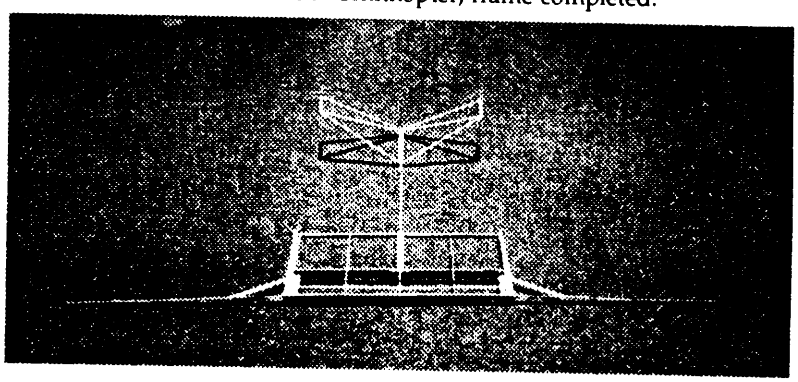
In January 1993, the modifications were made (above), and Electric Dawn was being tested in a small parking lot surrounded by trees. In those days, when I didn't know whether or not a new experimental design was going to fly, I often didn't worry about how much room it had available. I took a few steps forward and let it fly out of my hand. It flew straight and level, right into a tree. There it thrashed around like a psychotic heron until it flopped onto the ground. The only damage was a torn wing, which was promptly mended with tape. The flight was repeated several days later and photographed. This partially successful model (above) had triangular-planform wings spanning 4 feet. The wing covering of thin plastic could form a rough, cambered cross-section due to the unique bamboo "ribs." Energy was concentrated in the downstroke by a pair of rubber bands attached to the wings. The problem was, the performance wasn't great. I wanted climbing, not just level, flight.

I thought I might solve this problem by using a more efficient, double-throw-crank, flapping mechanism. This required a different layout and an extra ounce of weight. The new Electric Dawn (shown) had a 54" wingspan, at the center of which was a fixed wing. Long pushrods flapped the wings, and the opposing forces on the two pushrods reduced the lateral force on the crankshaft bearings. This new configuration was tested in June, 1993, in a somewhat larger field. The first flight descended gradually in a wide circle, ending up nearly 100 feet away. By adjusting the flapping angle of one wing, I was able to compensate for the turn. On its second and third flights, ED 54 covered a few hundred feet or so, setting a record for the straightest ornithopter flight ever.

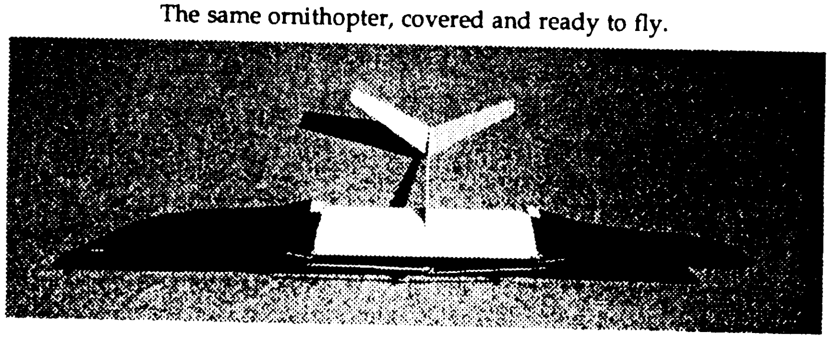
The geartrain had served well, considering that it was designed for a lot less power. It often ate up gears, but I had plenty of replacements. Sometimes the final gear came loose from the crankshaft, but I simply epoxied it back on. However, whenever I attempted to fly the ornithopter with all four cells, gear teeth rained down from the squawking bird. I had happened across a more robust gear which would nicely replace the last black gear in the HLH731. Reluctantly since the use of scavenged parts would make it difficult for others to duplicate my ornithopter, I used this secret weapon gear, and it was just what Electric Dawn needed to rise into the air.

The climb was into a headwind, so I cannot estimate the distance covered. However, the ornithopter was about 20 feet above the ground before anything went wrong. Then it started pitching erratically and soon found its way to the ground. Two defects were apparent, either of which could have caused the crash. The final gear had come lose again. Additionally, the battery pack was no longer taped to the fuselage. If this had come loose during the flight, it would have shifted the center of mass and produced the observed dives and erratic flight. Rather than repair the model and fly it again (never knowing how long the magic gear would last, and I had only one), I decided to try building a new geartrain from other available parts. I have only begun construction of the new model, and I don't know when it will be finished. It will be as heavy as ED 54, but will not have the fixed center section. Major improvements will include a stronger, more efficient, two-stage reduction gearing, ball bearings on the crankshaft, and a more birdlike appearance.

Electric Dawn 54" ornithopter, frame completed.



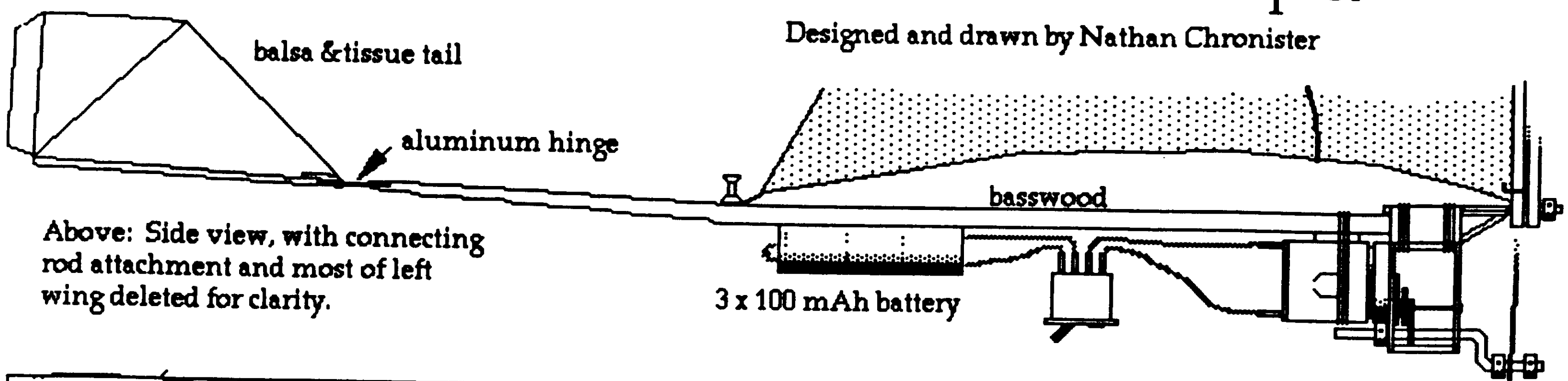
The same ornithopter, covered and ready to fly.



Nathan Chronister

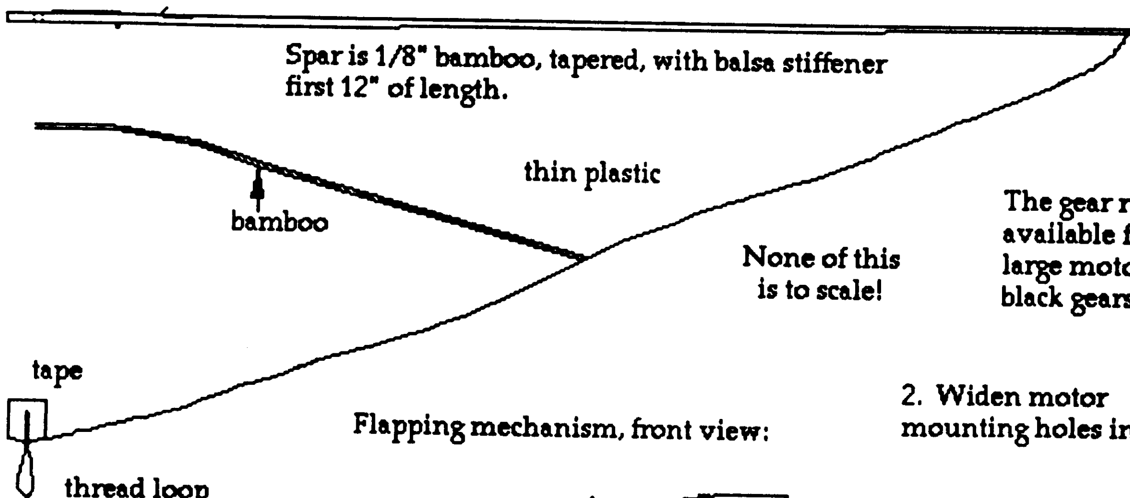
Electric Dawn ornithopter

Designed and drawn by Nathan Chronister



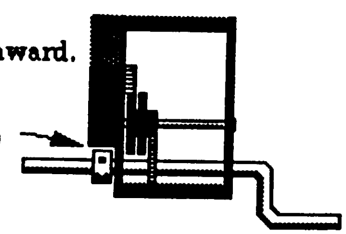
Above: Side view, with connecting rod attachment and most of left wing deleted for clarity.

Motor: M-25 motor from VL Products. Request one without the prop adaptor (bare shaft).

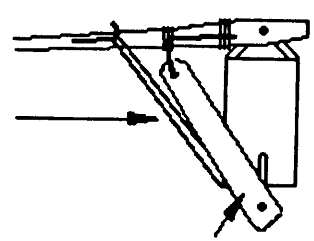


The gear reduction unit in this model is available from Hobby Lobby: HLH731 large motor geartrain using two of the black gears, with the following changes:

1. Remove screw mounts.
2. Widen motor mounting holes inward.
3. Cut away plastic to clear the collar.
4. Cut away the integral spacer which keeps the second black gear away from the metal gear. Replace it with a new washer made from plywood.



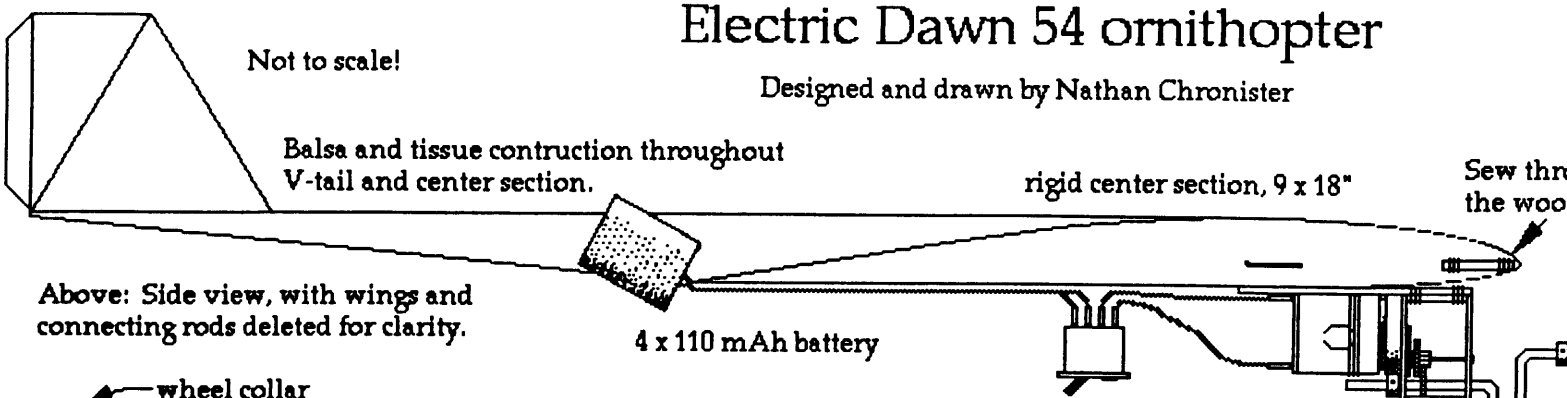
Flapping mechanism, front view:



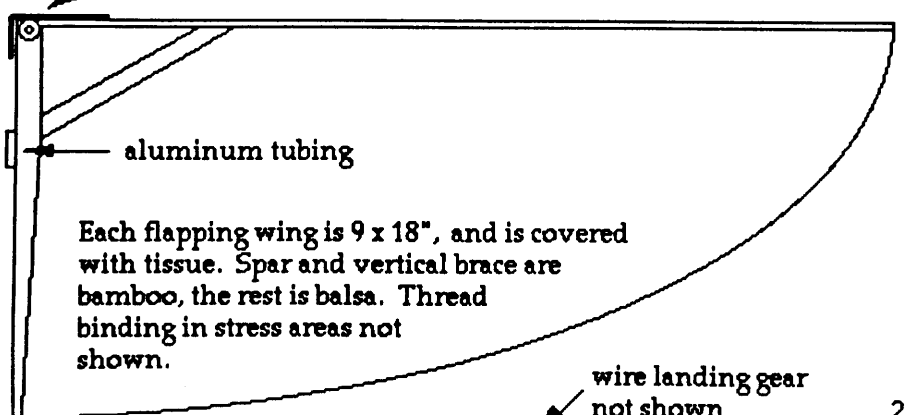
Electric Dawn 54 ornithopter

Designed and drawn by Nathan Chronister

Not to scale!



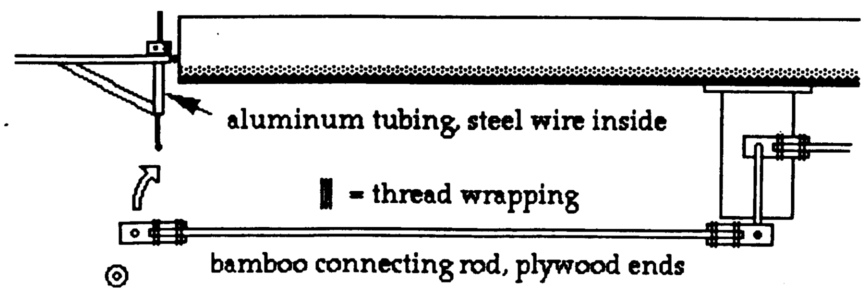
Above: Side view, with wings and connecting rods deleted for clarity.



Each flapping wing is 9 x 18", and is covered with tissue. Spar and vertical brace are bamboo, the rest is balsa. Thread binding in stress areas not shown.

wire landing gear not shown

Flapping mechanism, front view:



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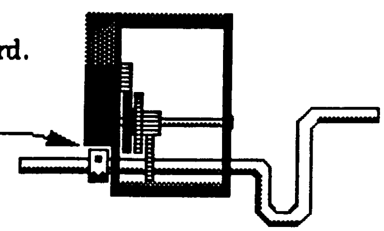


4. Replace second black gear with a stronger one.
5. Cut away the integral spacer which keeps the second black gear away from the metal gear. Replace it with a new washer made from plywood.

Everyman's guide to...

Ornithopters

John White takes us through some of the design considerations to achieve the oldest form of flight.

John White explains some principles behind his successful Ornithopters

Winged flight

Before M. Penaud invented the propeller in the 1870's (fig. 1) climbing flight had been achieved only by means of beating wings. Many species of living creatures were successful. It is thought that among the first were the dragonflies. Fossilised remains have been found that show they existed three hundred million years ago. With wingspans of up to thirty inches they were much larger than present day species.

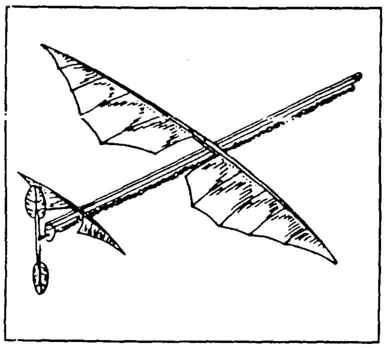


Fig. 1. The 'Aeroplane' by M. Penard. Note the use of feathers for propeller and stabiliser.

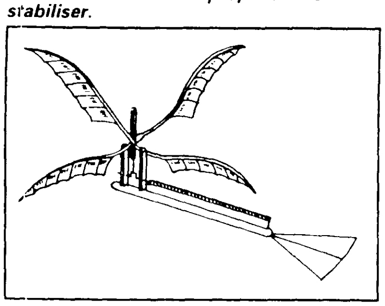


Fig. 2. The artificial dragonfly built by M. Jobert.

Ornithopters [from the Greek ornith (bird) + pteron (wing)]

Ornithopters are machines that fly by beating their wings. In the early 1870's a Frenchman, Jobert, built an artificial dragonfly (fig. 2). In the 1880's several models were built - notably the 'Bird' by Mr. Tatin (fig. 3).

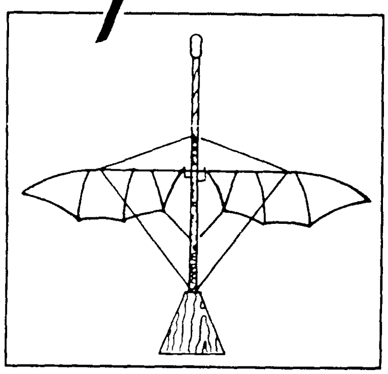


Fig. 3. Mr. Tatin's ornithopter the 'Bird'.

On December 17th 1903 came the historic flight of the Wright Brothers at Kitty Hawk. Research and development was then directed towards fixed-wing aircraft. However, many enthusiasts continued to experiment with ornithopters. Among them were Dr. Lippisch who designed 'Schwingin' in 1937/8 and Dr. Eric von Holst who designed 'Buzzard' in 1939. Parnell Schoenky designed 'Flap Happy' in 1949.

Leonardo de Vinci thought the bird a machine that operated according to mathematical law, but the analysis of bird flight is very complex. Ron Waring in an article published in 1953 suggested that if we wanted a successful model ornithopter we would have to start by forgetting about bird flight.

The dragonfly is a very efficient flying insect and according to some estimates it is capable of speeds of up to 60 m.p.h. As its wing motion is relatively simple, I chose to experiment with ornithopters based on the flight of the dragonfly. In 1954 I developed the phased bi-plane that enabled model ornithopters to achieve climbing flight. Almost 40 years later there is still much more to be learned about the design of ornithopters. The following are my own views, formed by study and practical experience.

Ornithopter wings

The wings of an ornithopter are pivoted at their root to a fixed structure called a cabane. Wings are the model's propellers, providing thrust. A suitable power source must be available, which when linked to the wings, causes them to beat up and down.

Fig.4 shows the construction of a typical wing. Note that the only rigid parts are the root bar and brace. The leading edge must be light but strong enough to resist undue flexing in both vertical and horizontal planes. The choice of material depends on the size of the model and whether it is designed as an outdoor or indoor model. I have found that tapered cane is best for outdoor models. The tissue may be strengthened with a flexible non-shrinking dope. The grain of the tissue is best across the chord.

Ornithopter wings usually copy the dragonfly wing in depending on air pressure to form the tissue to a shape similar to that of a propeller blade. The tension and the plan form of the tissue plays an important part in the shaping of the wing under power. It is best viewed in stroboscopic light. One wing of an ornithopter is not counterbalanced by the weight of the opposite wing, as are the blades of a propeller. For this reason the wings should be made as light as possible. Lift is obtained by giving the wings a high angle of attack. Fig. 5 shows a tail plane with a large angle of elevation enabling the wings to provide lift.

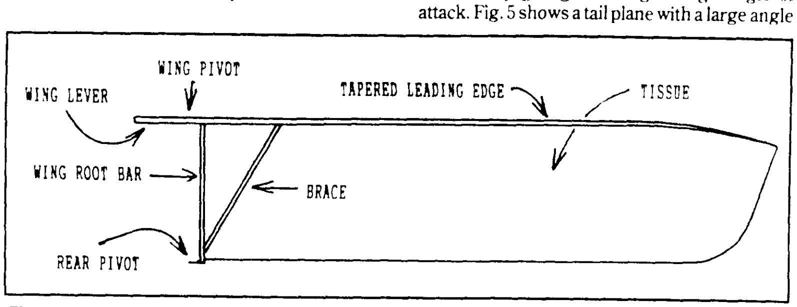


Fig. 4. A typical ornithopter wing.

Linkage systems

An important part of any ornithopter design is the linkage that connects the power source to the wings. Wings are normally operated by rods connected to a continuously rotating crank shaft. The linkage may take many forms, some of which are shown in fig. 6.

In designing a linkage system try to arrange for the wings to beat sinusoidally. This means

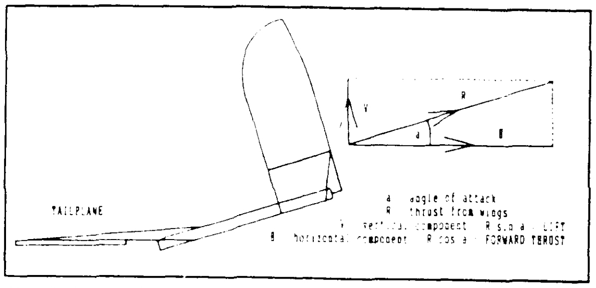


Fig. 5. Shows the attitude of a model to obtain lift.

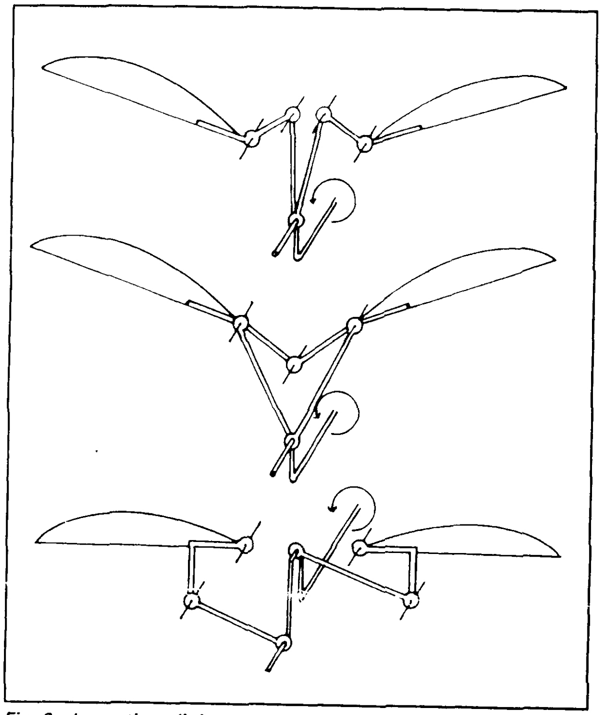


Fig. 6. shows three linkage systems.

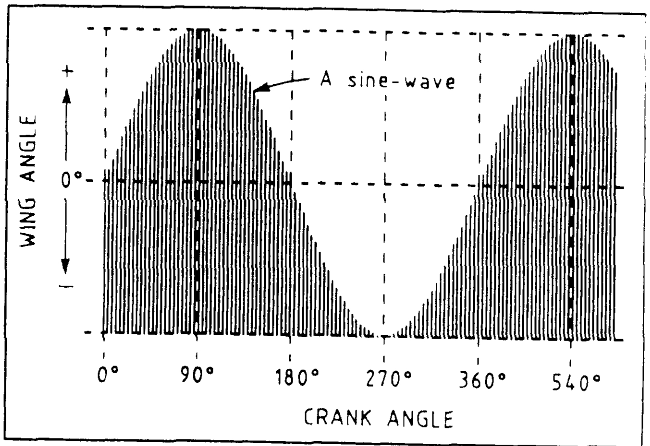


Fig. 7. The Graph of Wing Angle versus Crank Angle.

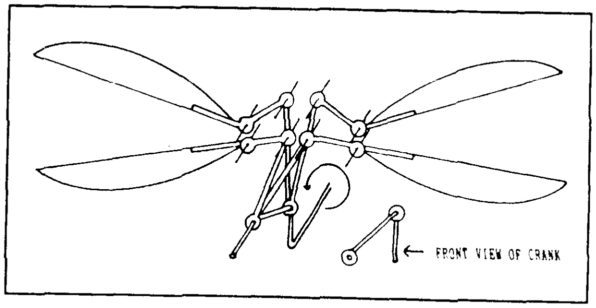


Fig. 8. A double-throw crank.

that if the wing angle is plotted against crank angle the resulting curve is a sine-wave (fig. 7).

This wave-form is difficult to achieve. I have found that if the length of the conrod is made equal to the vertical height of the wing pivots above the crank centre, and the ratio of this height to the crank radius is made as large as practical, a close approximation may be reached. A wing offset angle should be chosen so that the mean sweep angle of the wing is at a dihedral angle sufficient to provide stability. Make sure that the angle between the wing radius arm and the conrod is not too acute or too obtuse. Otherwise it is likely that the radius arm will toggle and lock up.

Motive power

Power to drive the wings usually comes from a rubber motor as a high level of torque is required. Electric motors and I.C. engines need large reduction gears which reduces their power/weight ratio. An ornithopter with a single pair of wings does not utilise the power of the motor efficiently. Approximately half the energy is wasted. The resulting vibration requires the model to be built robustly. This increases its weight and so reduces its efficiency.

Bi-plane ornithopters

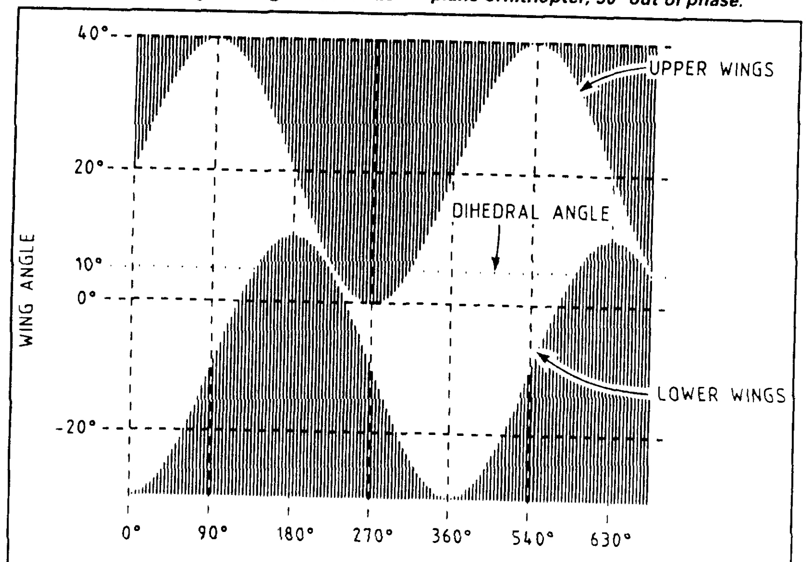
By adding a second pair of wings out of phase with the first pair almost all the power may be utilised. There is less vibration and the model weight can be greatly reduced. If both pairs of wings are beating sinusoidally with a phase difference of 90 degrees, the transfer of power should be at a uniform rate. In addition, if the offset angles of the wings are adjusted so that the upper and lower wings meet, greater thrust can be generated.

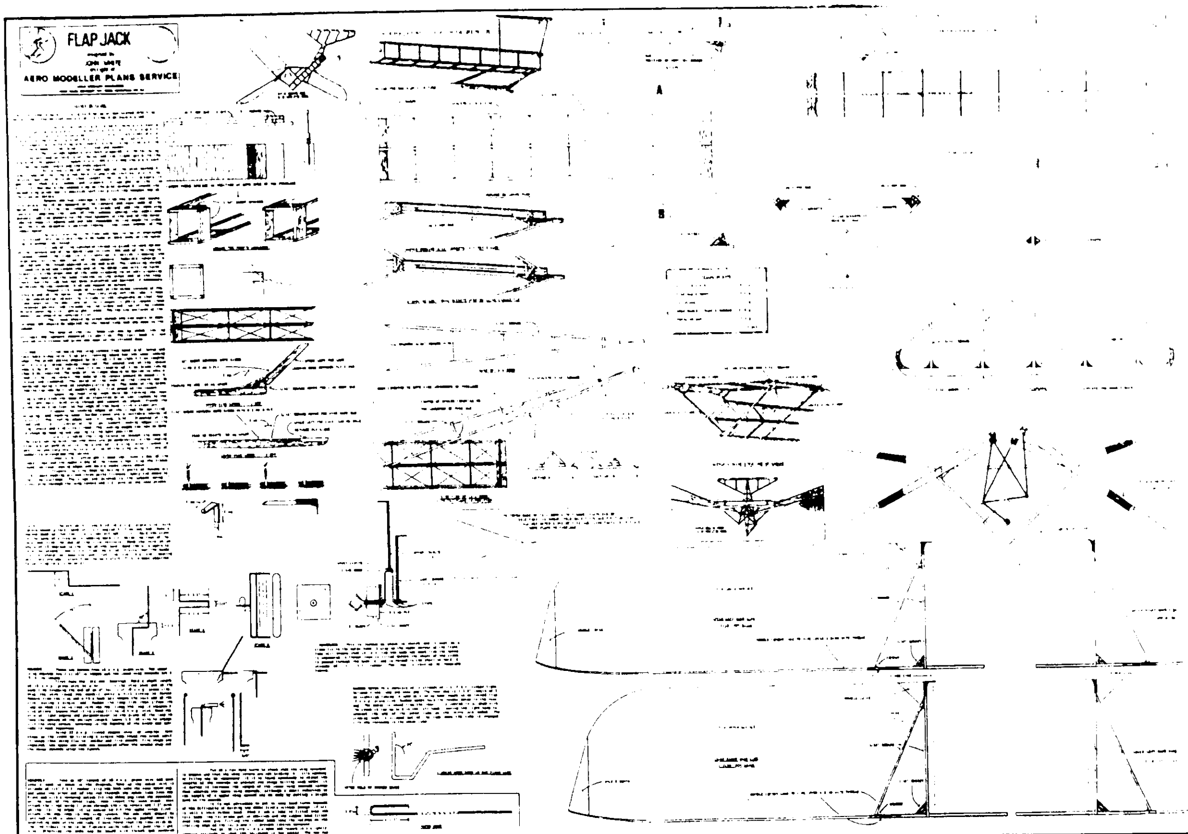
Fig. 8 shows a double-throw crank with a phase angle of 90 degrees. Fig. 9 shows the waveforms of two pairs of wings almost touching at a dihedral angle of 10 degrees.

My latest model, plans of which are to be published, should make a useful starting point for the experimentally-minded modeller.

Ornithopters

Fig. 9. Waveform of the wings of a bi-plane ornithopter, 90° out of phase.

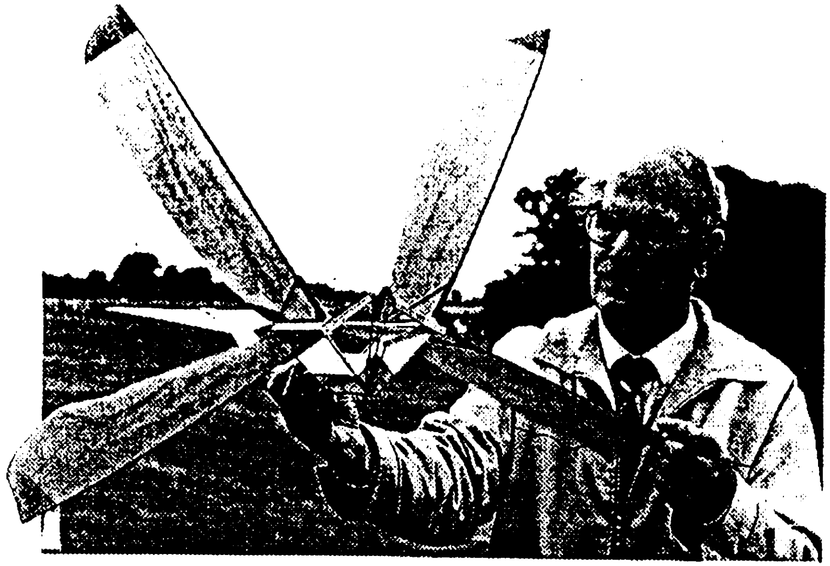




FLAPJACK

Full-size copies of the Flapjack plan are available as AM1716, price £5.75 including postage and packing, from Aeromodeller Plans Service, Argus House, Boundary Way, Hemel Hempstead, Herts, HP2 7ST. Model Pilots' Association members need only send £5.15

Following his article discussing some of the theory of ornithopters last month, John White has now drawn the plans and offers building instruction for one of his advanced models. It sets a unique challenge and flies extremely well



This is the model John flew at Old Warden last year in less than ideal conditions – wet and windy. It finished up in a tree but the damage was not too bad.

The right John White

John White was Head of Upper School at Woodbridge High School and should not be confused with his name sake who is the enthusiastic CDH designer and competitor. Now retired, this John flew his latest 'bi-plane' ornithopter at Old Warden last year and at the Model Engineer Exhibition this year. It created considerable interest and amazement. The sight of the model beating its way up into the air like a large living creature was spectacular.

It started in 1949

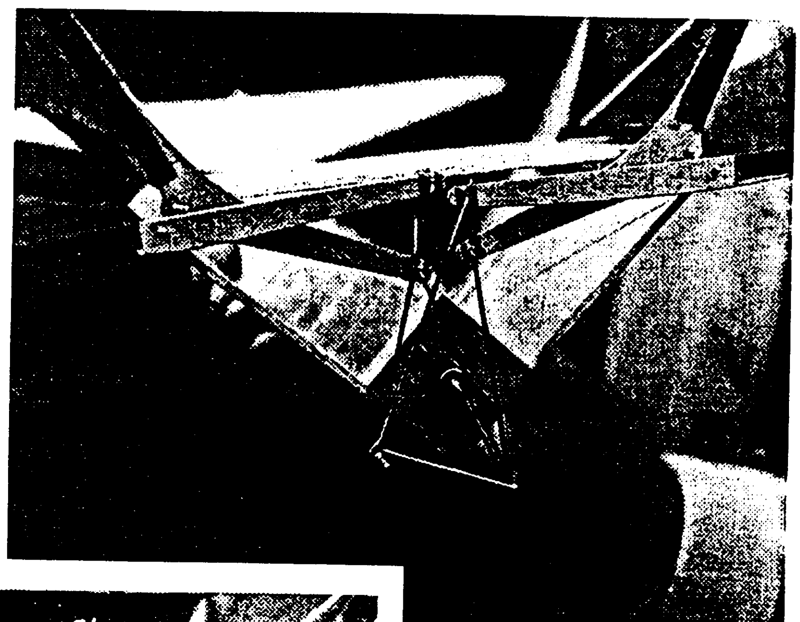
John's interest in ornithopters was aroused when in 1949 Aeromodeller published the plans of Parnell Schoenky's Flap Happy. He quickly came to the conclusion that a single pair of flapping wings operated by a simple crank mechanism was inefficient. When the crank was passing top or bottom dead centre the wings hardly moved. This caused the crank to crack over. It speeded up and then suddenly slowed as the wings acted as an air brake. The resulting vibration put a great deal of strain on the airframe, requiring it to be strongly built.

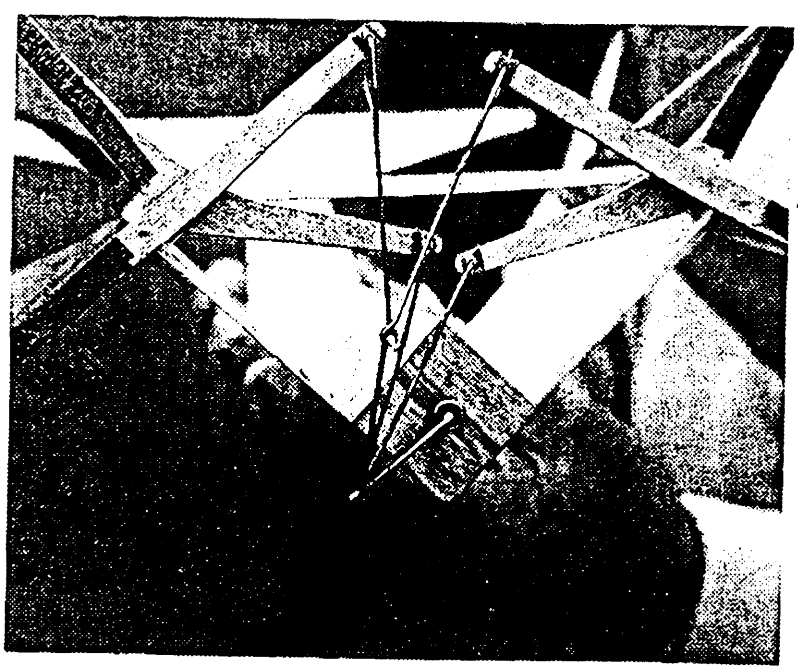
He then began to design and build models that used a second pair of wings. One pair to beat one quarter of a revolution out of phase with the other pair. When the crank was at top or bottom dead centre for the upper wings the crank was operating the lower wings at maximum power, and visa versa. The reduced vibration allowed the airframes to be made much lighter. Jack Holt of the old Hornchurch Club assisted him in the design of the rubber motors. His experiments resulted in 'DRAGONFLY' which set a record of 1 minute 55 seconds at Langley Aerodrome, Bucks on the 20th of June 1954.

Still experimenting

Recently he has been experimenting with electric-powered ornithopters. Since joining the Chelmsford M.F.A. last year his interest in rubber-powered ornithopters has been re-awakened. With the help and encouragement of the club's free-flight enthusiasts he has improved his design.

The construction of the model is very unusual so it was decided to put the step by step details of each stage of construction on the plan and not in the usual separate article. Many who buy an Argus plan neither have nor need the relevant Aeromodeller article, but for this model John's excellent diagrams and instructions are a must. We endorse Flapjack as an ornithopter that will provide hours of pleasure and could be the starting point for the experimentally minded modeller. There is much more to be learned in this fascinating branch of the hobby.





The key to John's brilliant achievement with model ornithopters is the phased flapping of two sets of wings. Here we can see the cranks in two positions in the sequence. It is fully explained on the plan. On the smaller version flown indoors, he tells us the arms have been reinforced with cyano.