Ornithopter Modeler Society Newsletter

AUTUMN 1985

flapper facts

VOLUME II NUMBER IV PATRICK J. DESHAYE, Ed.

ANTIEDITORIAL

There will be no editorial in this issue.

True,

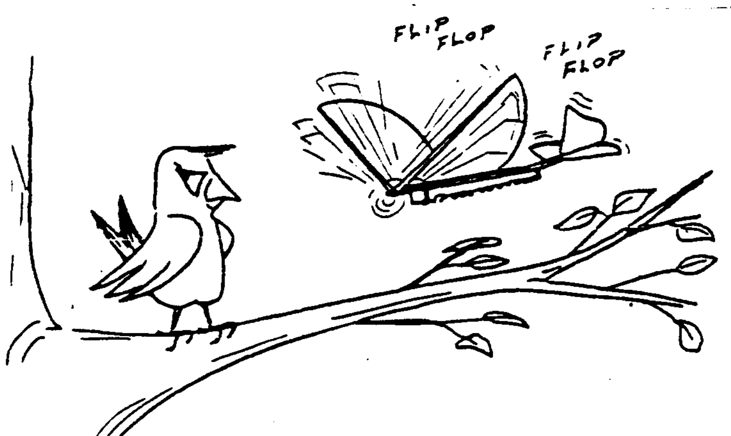
IN THIS ISH:

Maybe we should make some mention of something from the last issue: the Kieser bipe canard plans are now worth ten minutes, 36 seconds! See the in-flight picture (stolen from Model Aviation) and a few more details on our president's unique ship inside... remember, save those plans!

That ornithopters probably function within a more complex aerodynamic realm beyond that of more conventional craft should come as no surprise; but that much of the more recent biologic/aerodynamic interdisciplinary research is making some headway into understanding these nonsteady aerodynamic forces acting on small flapping wings is exciting. For this reason an explanatory article appears inside. It was stolen from Science, June 14, '85 issue.

The "Applied Freethinking" award goes to new member Les Garber, whose 4 1/2 minute biplane plans and article appear within. Garber hasn't copied anyone-- his machine has only three moving parts, two of which are the wings, which describe a unique flapping motion. His duration may not seem like much in these post-Rohrbaugh days, but bear in mind that 1) his ornithopter is still in its early test-bed stage of development, 2) less than a year and a half ago his device would have been a record-setter... this with a completely original, pioneering design.

Please Please Please fill out and send in the questionaire, everyone. This is very important to our organization on all levels, and will ensure that you get your money's worth and that our organizational posts will be filled next year. Pat will serve as Editor for one more issue of FF, so we will need a new Editor... Any takers? C'mon...



"THAT'S IT! I'M SWEARING OFF THOSE FERMENTED BERRIES FOR GOOD."

From Model Aviation Canada, submitted by Bob Meuser

←

ORNITHOPTER ACTIVITIES by Frank Kieser

May 10, 1985 Ray Harlan set a Cat. II record of 7 min. 08 sec. at Andover Academy (35 ft.)

June 29, 1985 - Ray Harlan set a Cat. I record of 4 min. 59 sec. at the MIT Ice Rink (26 ft.)

June 18, 1985 - U. S. Indoor Championships, Niagara Falls, NY Cat. III - The ornithopter event was won by Frank Kieser flying his canard biplane for a time of 5 min. 46 sec. Second was Les Garber flying a unique see-saw biplane for a time of 4 min. 37 sec. Third - Joe Krush, 3 min. 09 sec. Fourth - Jeurgin Kortenbach 2 min. 35 sec.

July 6, 1985 - AMA Record Trials, Goodyear Air Dock, Akron, OH On his last flight of the day, Frank Kieser had a record flight of 10 min. 36 sec. (Cat IV) reaching an altitude of approximately 160 ft. On the previous day, Ray Harlan turned in a time of 9 min. 21 sec.

August 1, 1985 - Free Flight Symposium at AMA Nats. The Symposium was chairmaned by NFFS President Tony Italiano and held at the Quality Inn in Chicopee Mass. To an audience of over 100 free flighters, Hewitt Phillips presented his paper The Fuselage Motions of Ornithopters and Frank Kieser gave a talk on Ornithopter Design. Tony presented NFFS awards for the 1985 Free Flight Hall of Fame and the top 10 models of 1894 including Al Rohrbaugh's record breaking ornithopter.

Dragonfly Flight: Novel Uses of Unsteady Separated Flows

Abstract. *Studies of insect flight have revealed novel mechanisms of production of aerodynamic lift. In the present study, large lift forces were measured during flight episodes elicited from dragonflies tethered to a force balance. Simultaneously, stroboscopic photographs provided stop-action views of wing motion and the flow-field structure surrounding the insect. Wing kinematics were correlated with both instantaneous lift generation and vortex-dominated flow fields. The large lift forces appear to be produced by unsteady flow-wing interactions. This successful utilization of unsteady separated flows by insects may signal the existence of a whole new class of fluid dynamic uses that remain to be explored.*

Many insect species exhibit flight behaviors not readily explained by conventional steady-state aerodynamics (*1, 2*). Using high-speed photographic records of hovering chalcid wasps, Weis-Fogh (*2*) observed a wing upstroke completed by a dorsal clap and a downstroke initiated by a flinging apart of the wing leading edges. These so-called "clap" and "fling" movements were purported to induce both temporally and spatially dependent circulations about the wings that accounted for large unsteady lift forces. The estimated lift values were consistent with the observed hovering behavior. Analytic evaluations (*3*) corroborated the postulated underlying unsteady fluid mechanics. Using physical models to simulate the Weis-Fogh mechanism, Maxworthy (*4*) visualized these unsteady separated flows and suggested that they play a larger role in the production of lift than had been predicted. Theoretical (*5*) and experimental (*6*) analyses have further characterized the influences of unsteady separated flow on the Weis-Fogh mechanism of lift production. These studies indicated that novel unsteady fluid mechanisms can be used by certain insects. Moreover, these unsteady separated flow mechanisms, based on the same wing geometry and kinematics, appear to generate more lift than do steady-state mechanisms.

In this study we correlated dragonfly wing kinematics with lift history and the structure of the surrounding flow field. This insect exhibits a proficient flight capability with relatively simple, fixed-geometry wings. Its major flight modes include stationary hovering or slow hovering in any direction, high-speed upward and forward flight, and gliding flight. Earlier studies (*2, 7*) indicated that, for dragonfly hovering, calculations based on steady-state aerodynamic theory do not produce the lift values necessary to counterbalance the weight of the insect (*8*). In fact, the large geometric attack angles of the wings characteristic of dragonfly hovering may result in a total separation of the boundary layer that precludes the use of steady-state mechanics.

In evaluating the mechanisms of dragonfly flight, physical characteristics were measured, wing kinematics were documented photographically, lift production was correlated with wing motions, and flow was visualized to reveal associated perturbations in the flow field. The results indicated that the dragonfly generates and controls unsteady separated airflows to produce lift. The manner in which the dragonfly does so, however, differs from that reported for the chalcid wasp.

Twenty-one dragonflies (*Libellula luctuosa*) netted in habitats near the University of Colorado, Boulder (~1600 m above sea level), were used for this study. Within 1 hour of capture, each dragonfly was temporarily immobilized with chloroform (or cooled to approximately 10°C) to simplify measuring and tethering. The average total area of the two wing pairs on each insect was 16 ± 1 cm^2 (mean ± standard deviation) and the average body mass was 340 ± 36 mg, so that the typical wing loading was 2.1 ± 0.2 N m^{-2}. The ratios of the square of the wingspan to the wing area (aspect ratios) were between 8 and 9 for the front wings and between 6 and 7 for the rear wings. Such aspect ratios are typical of enhanced lift-to-drag ratios (due to reduced wing-tip effects) used in gliding flight. Ratios of wing thickness to chord thickness ranged from 0.01 to approximately 0.05, indicating that the dragonfly wing can be approximated by a Blasius flat-plate model.

Dragonflies were tethered with cyanoacrylate adhesive at the ventral aspect of the synthorax to a one-dimensional force balance so that vertical lifting forces could be measured during flight episodes. Thirty minutes after tethering, insects were placed in a zero-flow environment, and flight episodes lasting 2 to 3 seconds were elicited two to three times per minute over a total test time of 10 to 15 minutes. Throughout tests there was no change in lift force or wing dynamics of the insects. The output of the force balance was continuously monitored by oscilloscope, and stroboscopic photographs were taken simultaneously with a 0.4-msec flash (2900 beam candle power seconds) positioned 28 cm above the insect. A light-sensitive diode was used to indicate the instantaneous lift force corresponding to the visualized wing configuration (Fig. 1).

Resulting views of wing motions were similar to those observed for tethered (*9*) and free hovering (*7, 10*) dragonflies. Correlated patterns of lift generation were repeated approximately every 36 msec, so that wing-stroke and peak lift-force frequencies averaged 28 Hz. The basic motion of the wing tips was down and forward during downstrokes and up and rearward during upstrokes (Fig. 2, A and B). Viewed from the side, the upper half of the stroke plane of each wing pair was inclined 30° behind the vertical and the bottom half was 40° forward of the vertical. Geometric attack angles (acute angles measured from the stroke plane to the wing-surface plane) were estimated to be as large as 50° to 60° during downstrokes. During upstrokes wing attack angles decreased from the root to the wing tip because of spanwise twisting but still averaged a relatively large 20° to 30°. Rapid changes in attack angles were observed at the bottom of each downstroke, when the wing leading edges pitched up (supinated), and at the top of each upstroke, when the leading edges pitched down (pronated). The hind wings normally led the front pair through a stroke, with a phase-angle difference varying between 50° to 100° (Fig. 2, A and B). Average velocities of the wing-tips (~300 cm sec^{-1}) were larger during upstrokes (~350 cm sec^{-1}) than during downstrokes (~250 cm sec^{-1}). These values were obtained from stroboscopic visualizations that showed high reliability across tested specimens, with minor variances observed only in stroke rate and amplitude.

Fig. 1. A typical photograph used to correlate configurations of the dragonfly wings (left) with instantaneous lift generation (right). A spike in the lower oscilloscope trace generated by a light-sensitive diode marks the instantaneous force-balance output in the upper trace. Approximately three full cycles of the wings (hind pair marked in black near the tips) are represented by the three lifting cycles displayed on the upper oscilloscope trace. The horizontal oscilloscope sweep moves from right to left (total duration, 120 msec) in these mirror images.

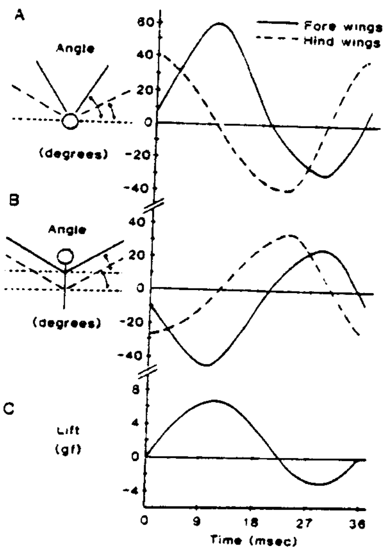


Fig. 2. A summary of an average dragonfly stroke cycle normalized to a 36-msec stroke period. Wing angles are summarized for observations from the front (A) and top (B) of the tethered dragonfly. Measurements of the corresponding lift (C) were estimated by subtracting the resonance values contributed by the mounting device (~55 Hz) from the total measurements of the force balance (1 gf = 9.81 × 10^{-3} N).

Force-balance measures revealed unsteady lift patterns, with smooth peaks of 5 to 7 gram-forces (gf) (4.9 × 10^{-2} to 6.9 × 10^{-2} N) during a typical test (Fig. 2C) (*11*). Thus, for an instant during each stroke cycle, a dragonfly weighing 0.34 gf produces lift forces 15 to 20 times its body weight. The average sustained lift was less than this but still amounted to more than twice body weight.

Correlations of lift history with wing kinematics (Fig. 2) showed that positive lift begins as the rear wings pronate and then accelerate into a downstroke. Lift increases steadily through the first half of the downstroke and reaches a maximum as the wings pass through the horizontal body plane. This lift maximum occurs 8 to 10 msec after a pronated rear wing slips past a supinated front wing. Lift drops toward zero during the second half of the rear-wing downstroke and becomes negative through the following upstroke. The first half of the front-wing downstroke coincides with a positive but decreasing lift, while the second half coincides with negative lift.

Flow visualization techniques were used to reveal the pattern of airflows interacting with the dragonfly during elicited flight episodes. A vaporized kerosene smoke was delivered (velocity, ~20 cm sec^{-1}) through Tygon tubing (1 cm in diameter) to a region directly in front of the insect. During flow visualization tests, limited to 5 minutes or less, behavior patterns did not differ from those observed in the absence of smoke. Flow visualizations, recorded photographically, revealed a prominent wake flow field behind the dragonfly. This wake described a symmetric wedge shape about the horizontal (apex angle

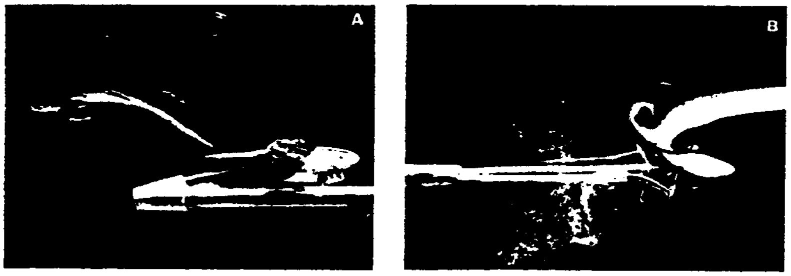


Fig. 3. (A) Stroboscopic photograph showing a typical wake flow field behind a tethered dragonfly. The insect is facing right with both wing pairs in the lower stroke plane. The mounting strut (thickness, ~12 percent wingspan) is positioned below and parallel to the dragonfly body to minimize interference with the induced flow field. Both a laminar vortex-dominated flow above the horizontal plane of the insect and a turbulent region below are apparent. The upper flow of this complex wake may arise from residual structures such as those in (B). (B) A multiple (four to five) exposure photograph of the phase-locked wing motion and associated flow field around the forewing (the other three wings have been surgically removed) of an automaton model (*13*) of the dragonfly (facing right). Wing motion is driven by electrical stimulation of flight-sensitive neuromuscular systems. When shed from the wing surface during a wing downstroke, vortex structures such as those shown gradually dissipate with convection away from the insect.

varying between 20° and 180°) which ranged from 5 to 15 cm in length. Although generally turbulent in appearance below the horizontal, above the horizontal the wake region often displayed a clearly defined character in which localized vortex stacking was evident (Fig. 3A). Previous model studies (*12*) suggest, and our follow-up studies (*13*) corroborate, that vortices and unsteady flow interactions are produced by dragonfly wing motions (Fig. 3B).

Nonsteady wing motions, such as rapid changes in wing attack angles and velocities, although necessary to support unsteady fluid mechanisms, are not sufficient to indicate a significant dependence on unsteady separated flows to generate lift. For example, during normal hovering as exhibited by many insects, the wings move in a horizontal figure-eight stroke plane at relatively small attack angles. For these insects, steady-state aerodynamic calculations yield lift values large enough to support the insect during hovering (*2*). However, in the dragonfly the stroke plane is nearly vertical, the wing pairs beat independently at large geometric attack angles, and the surrounding flow field is dominated by unsteady structures. Perhaps more important is that the tethered dragonfly produces a nonsteady lift history with large transient lift peaks 15 to 20 times its body weight. Even when time-averaged across a full stroke, our force balance data indicate that a tethered dragonfly generates a sustained lift two to three times its body weight, possibly indicating coefficients of wing lift, C_L, larger than the values of 2.3(*2*) and 6.1(*7*) predicted for sustained hovering. Such high C_L values are incompatible with steady-state aerodynamics at the associated Reynolds numbers of 1000 to 2000 (*8*). These data are suggestive of one or more unsteady fluid mechanisms that act in the production of lift for the dragonfly (*14*).

Unlike the chalcid wasp, dragonflies do not exhibit "clap" and "fling" wing movements. The front and rear wings are not latched together. Dragonflies operate their front and rear wing pairs independently, maintaining a specific phase relation between the wings. Visualization of the associated flow revealed an unsteady field different from that predicted and modeled for the "clap" and "fling" mechanism (*2, 4*) of the wasp.

The active changes in wing pitch (pronation and supination) initiating both downstrokes and upstrokes, respectively, have been suggested to play a role in unsteady lift generation for the dragonfly (*2, 7, 12*). The fluid dynamic mechanisms underlying such unsteady effects have not been described. Although the present force-balance recordings do not rule out such unsteady effects (*11*), the single large lift peaks that occur once in each stroke period suggest that lift generation is dominated by the integrated interactions between wings rather than by the unsteady effects elicited independently by each of four wings.

On the basis of the measurements of the forces generated during the wing-stroke motions of four wings, there may be a requirement for coordinated interactions between the front and rear wings, as has been speculated (*7*). The high positive lift that is generated immediately after a pronated rear wing slips downward past a supinated front wing (Fig. 2) may indicate that highly energetic vortex flows separate from the upward moving front wing and then interact with the rear wing to produce high lift. Although our data suggest a controlled movement of vortices between wing pairs, the details of these flows remain to be measured and correlated with lift production.

The tethered dragonfly may not be a precise model of the insect in free flight, but the similarities in wing movements are remarkable. That the tethered dragonfly generates high lift makes underlying fluid-wing mechanisms worthy of further investigation despite any departure from normal flight conditions. Also, such fluid mechanisms may exist initially near a dragonfly escaping freely from rest. Additional flow visualization studies together with a multidimensional force-balance analysis should help to clarify some of the finer details of these novel mechanisms of lift production (*13*).

It seems clear that the total flight behavior of most insects depends on both steady and unsteady fluid mechanisms. During any particular flight mode, one type of mechanism may predominate. The use of complex unsteady separated fluid mechanisms need not imply the existence of complicated wing geometry, motions, or control. The dragonfly generates large aerodynamic forces by means of rather simple wing structures and kinematics. Moreover, these wing kinematics and associated flow fields are different from those postulated by Weis-Fogh for the chalcid wasp. These observations suggest a number of different mechanisms for the generation and use of unsteady separated flows by insects. Whether such mechanisms might be useful on a larger scale at high Reynolds numbers remains to be seen (*15*).

CHRIS SOMPS
MARVIN LUTTGES
Department of Aerospace Engineering Sciences, University of Colorado, Boulder 80309

References and Notes

1. M. F. M. Osborne, *J. Exp. Biol.* **28**, 221 (1951).
2. T. Weis-Fogh, *ibid.* **59**, 169 (1973).
3. M. J. Lighthill, *J. Fluid Mech.* **60**, 1 (1973).
4. T. Maxworthy, *ibid.* **93**, 47 (1979).
5. R. H. Edwards and H. K. Cheng, *ibid.* **120**, 463 (1982).
6. G. R. Spedding and T. Maxworthy, *Bull. Am. Phys. Soc.* **28**, 1401 (1983).
7. R. A. Norberg, *Swimming and Flying in Nature* (Plenum, New York, 1975), vol. 2, pp. 763–781.
8. By steady-state definition, the lift coefficient, C_L, equals $L/\frac{1}{2}\rho V^2 S$ and the Reynolds number equals $\rho V c/\mu$ where ρ and μ are the density and viscosity of the air, respectively, S is the wing surface area, and c is the average distance from the wing leading edge to the trailing edge. During hovering, each of the four wings of the dragonfly is assumed to develop an average lift force, L, equal to one-fourth the total insect weight. By assuming a simple harmonic wing motion and by making conservative estimates of the direction and magnitude of the velocities of

DRAGONFLY: A SIMPLE ORNITHOPTER

Lester W. Garber

1. Description of Design

Dragonfly is an ornithopter with a simple flapping mechanism. The front and rear wings 'teeter-totter' as opposed to flapping in a bird-like fashion. The mechanism has four parts; pushrods, crankshaft, and guideslot frame. The lower ends of the pushrods are rotated by the crankshaft. Pushrod travel is restricted by the guideslots. The wing centers travel an egg-shaped path while the wing tips follow a banana-shaped path.

The principal design parameters are the crankshaft radius, distance from the center of the crankshaft to the center of the guideslots, and the lengths of the pushrods. Despite the simple mechanism, the motions of the wings are difficult to visualize. Equations and computer programs were written to describe these motions as functions of the three design parameters.

The front and rear wings are very close together, this is dictated by design and (I think) aerodynamic considerations. Stiff pushrods, close tolerance bearings, and accurate dimensions are required or the wings will interfere with each other.

Certain aerodynamic phenomena can cause a fore and aft twisting of the wings: At high angles of attack, the wing half rotating down will have a greater relative air velocity than will the other half of the wing which is moving up. This causes more thrust on the high velocity side which causes a twisting moment on the wing and pushrod. The pushrod bearings must have close tolerances and the pushrods and wing spars must be stiff enough to resist the twisting force or wing interference will result.

For any ornithopter, the paths traveled by the wings can be divided into four regions: Up travel, up transition, down travel, and down transition. During transitions, the trailing edges of the wings have no vertical velocity (only the spar is moving), hence there is no thrust. Therefore the ratio of transition travel to upward/downward travel should be minimized. This can be can be accomplished with large flapping angles, narrow chords, and minimum chordwise angular changes during transition. Incidentally, during transitions, the wing membrane is slack. As the wing exits the transition region, the membrane is again made taut. This slackening and tightening of the wing membrane is the cause of the snapping sound associated with ornithopters.

The shape of the wing membrane during flapping critically affects efficiency and the relative ratio of thrust to lift. At one extreme the wing is simply a flag waving in the breeze with zero thrust and lift. At the other extreme the wing is a rigid plate with no chordwise angular change during up and down travel. In the second extreme no thrust can be generated. Somewhere between these two extremes lies the optimum ratio of thrust to lift.

It is more informative to view the wing as an oscillating propeller, not as a flapping wing. Then something can be said about the shape of the wing membrane. For example, the ideal membrane shape should be helical with a P/D ratio of about 2. In present designs the shape of the membrane is determined by air velocity, wing shape, and spar stiffness. Making wings work well is usually a matter of frustration, trial, and error. Perhaps a better design would have a wingtip rib hinged to the spar to allow angular rotation. During transitions the tips would rotate to a known angle of attack as determined by stop settings.

To date I have built some twenty versions of the enclosed design. Wingspans have varied from 12 to 24 inches. Weights have varied from a 2.8 gm, 12 in. model to a 1.25 gm, 24 in. model The larger models have failed (max. flight times of around 4 minutes) because of wing interference and excessive flexing of the wing membrane. Small sturdy models (12 in. span, 1.3 to 2 gms.) with tissue covered wings and stabs fly very well (1 to 3 min.).

The enclosed plans are for a version flown at NFFS contest at Niagara Falls,NY (June 85). Despite the small size and high flapping rate (190 cycles/minute), the longest flight was 4 min 35 seconds. I am working on a 1 gm, 17 in. version and have about solved the problems of wing shape and interference, so look out Frank Kieser!

2. Construction Comments.

The crankshaft, guideslot frame, and pushrods must be built with great care. Use good light, micrometer, and 640 grit paper. Measure everything, sand carefully, and bend accurately. With a bit of practice it becomes routine to work to +/- .001.

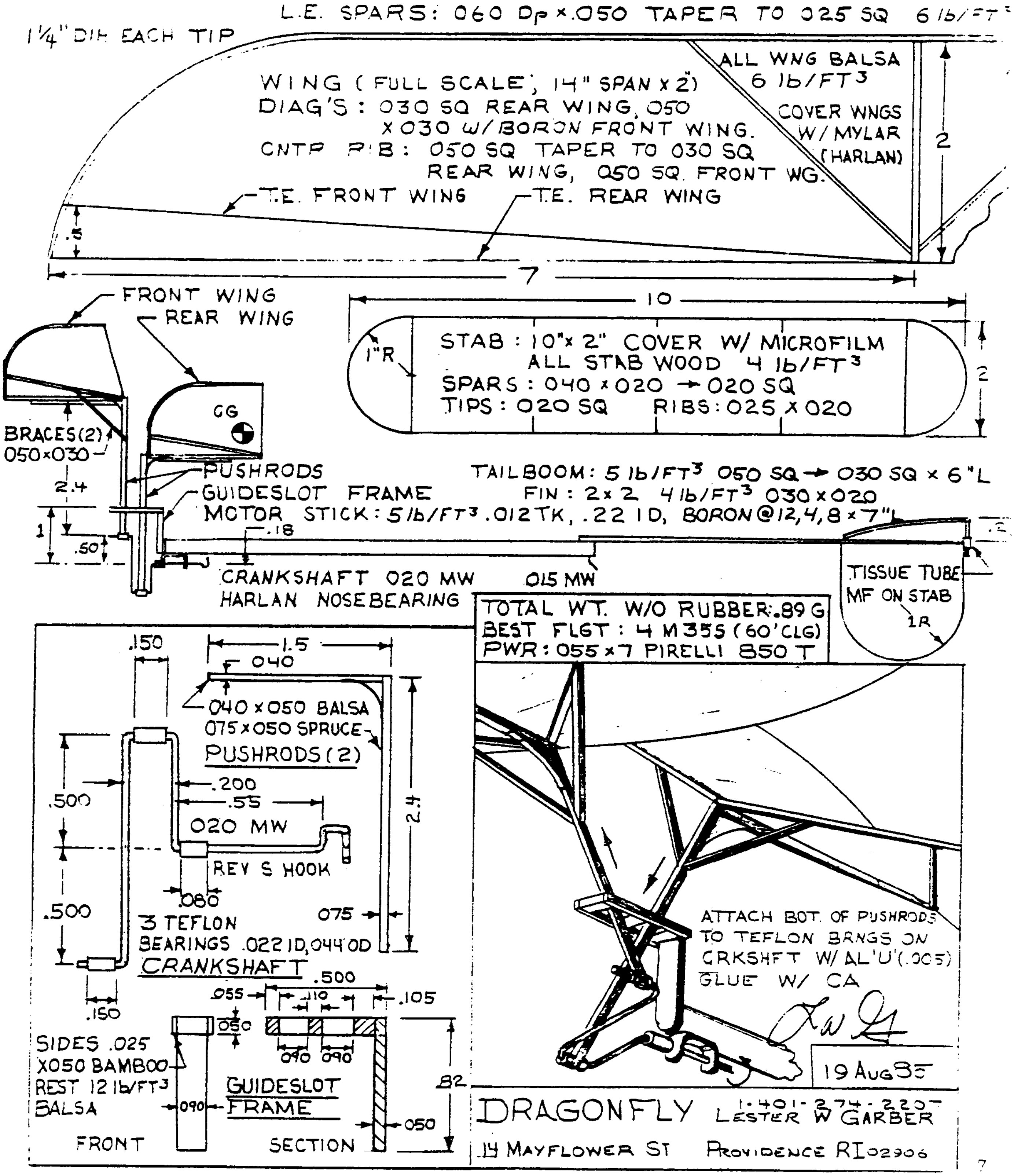
The crankshaft must be true in all angles and the bearings must be of minimum tolerance. I am not totally satisfied with the teflon bearing, thin wall brass tubing (.021 ID) might be better.

I use a spray adhesive (Duro) to stick mylar to wing frames. For each wing half, smooth mylar onto a flat surface, tape corners, and carefully lay frame onto film. Trim with carbon steel razor blade. Each CUT should be made with a new blade. The film should have the same amount of sag (very little and no large wrinkles) in all four wing halves. Wings must be warp free or the model will turn wildly to the right or left.

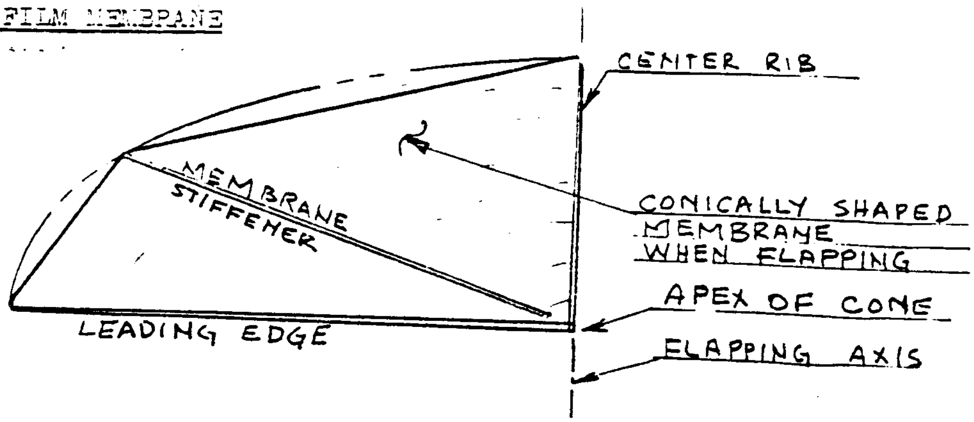
Motor sticks braced with boron and a kevlar spiral wrap (CCW, viewed from the rear) are light, stiff, and strong. Boron applied with small dots of cement every .20 in. weighs less than .001 gm/inch. But be ever so careful with boron, it's dangerous stuff!

Note CG location and make the tail as light as possible.

Use a graphite or teflon spray on guideslots to reduce friction.


L.E. SPARS: 060 Dp × .050 TAPER TO 025 SQ 6 lb/FT³
1¼" DIH EACH TIP
WING (FULL SCALE, 14" SPAN x 2")
DIAG'S: 030 SQ REAR WING, 050 X 030 W/ BORON FRONT WING.
CNTR RIB: 050 SQ TAPER TO 030 SQ REAR WING, 050 SQ. FRONT WG.
ALL WNG BALSA 6 lb/FT³
COVER WNGS W/ MYLAR (HARLAN)
2
T.E. FRONT WING
T.E. REAR WING
.5
7
FRONT WING
REAR WING
CG
BRACES (2) 050×030
2.4
1
.50
PUSHRODS
GUIDESLOT FRAME
MOTOR STICK: 5 lb/FT³ .012 TK, .22 I D, BORON @ 12, 4, 8 × 7"
.18
CRANKSHAFT 020 MW
HARLAN NOSEBEARING
.015 MW
10
1"R
STAB: 10"× 2" COVER W/ MICROFILM
ALL STAB WOOD 4 lb/FT³
SPARS: 040 × 020 → 020 SQ
TIPS: 020 SQ RIBS: 025 × 020
2
TAILBOOM: 5 lb/FT³ 050 SQ → 030 SQ × 6"L
FIN: 2 × 2 4 lb/FT³ 030 × 020
TISSUE TUBE
MF ON STAB
1R
TOTAL WT. W/O RUBBER: .89 G
BEST FLGT: 4 M 35 S (60' CLG)
PWR: 055 × 7 PIRELLI 850 T
.150
1.5
040
040 × 050 BALSA
075 × 050 SPRUCE
PUSHRODS (2)
2.4
.500
.200
.55
020 MW
REV S HOOK
.080
.500
3 TEFLON BEARINGS .022 ID, .044 OD
075
CRANKSHAFT
.150
.500
.055
.110
.105
.050
.090
.090
.82
SIDES .025 X050 BAMBOO
REST 12 lb/FT³ BALSA
.090
GUIDESLOT FRAME
.050
FRONT
SECTION
ATTACH BOT. OF PUSHRODS TO TEFLON BRNGS ON CRKSHFT W/ AL 'U' (.005) GLUE W/ CA
19 AUG 85
DRAGONFLY
1-401-274-2207
LESTER W GARBER
14 MAYFLOWER ST PROVIDENCE RI 02906

THIN FILM MEMBRANE



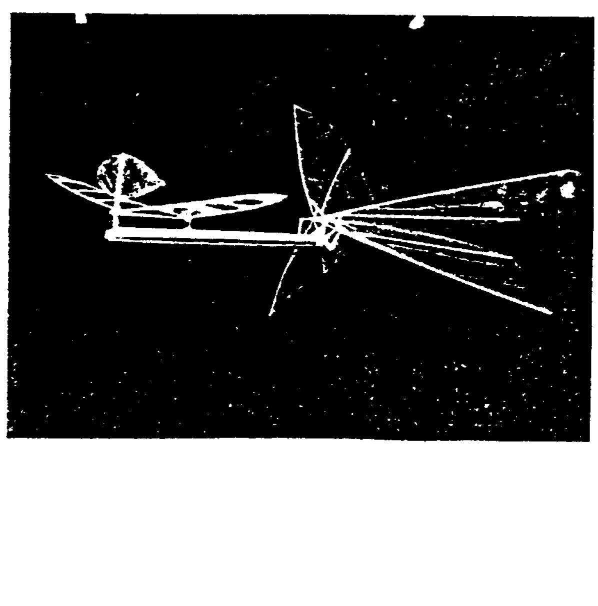
One of the covering materials available for membrane surfaces is the thin plastic film that is being used as a replacement for condenser paper. It is sold under the trade names "micro lite" (IMS & MicroX) and "ultrafilm" (Ray Harlan). The thickness of the film is in the order of 1.7 microns or 70 millionths of an inch. The weight is approximately .1 to .15 grams per 100 sq. inches. The suppliers furnish instructions on attaching to the frame and cutting but due to the extreme flexibility of the material, special consideration must be given to maintaining the membrane contour at the curved trailing edge.

The first point to realize is that the membrane surface approximates a segment of a cone whose apex is at the intersection of the leading edge and the center rib. If a membrane stiffener is placed as shown above, it will be on an element of the cone and therefore will be a straight line. The trailing edge shape can them be approximated by two straight lines, one from the LE to the stiffener and the other from the stiffener to the center rib. The membrane will then always maintain the desired conical shape. It has been my experience that the stiffener should be extended close to the LE/rib juncture.

I have used .020x.040 balsa on one side for the stiffener. Ray Harlan tells me he uses boron wire top and bottom. If adhesion of the membrane by spray adhesives is inadequate due to the flapping loads, small dots of liquid contact cement, particularly at the ends of the spar can reinforce the adhesion and prevent separation.

Frank Kieser 8/14/85

Any line ON THE SURFACE radiating from the apex is an element of the conical surface and by definition a straight line.



KIESER'S COMPUTER-ASSISTED DESIGN IN FLIGHT, AND DISPLAYING ITS MEMBRANE STIFFENERS...

OMS QUESTIONAIRE

NAME: ______________________

ADDRESS: ______________________

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AMA #: ______________________

+++TICKLER FILE INFORMATION+++

PLEASE WRITE DATE (Mo., Yr.) YOU SUBMITTED YOUR OMS DUES: ______________

OCCUPATION: ______________________

TELEPHONE: ( ) ______________________

LIST ANY OTHER AEROMODELLING ORGANIZATIONS OF WHICH YOU ARE A MEMBER: ______________

____

OUTSIDE INTERESTS: ______________________

____

WHEN AND HOW DID YOU START BUILDING ORNITHOPTERS? ______________________

____

WHAT HAS BEEN YOUR BEST PERFORMANCE/DURATION,OFFICIAL/UNOFFICIAL? ______________

____

WHAT PARTICULAR TYPES OF ORNITHOPTER INTEREST YOU MOST? (eg. monoplane, bipe, canard, engine-power, tailless, etc.)

____

WHAT DO YOU FEEL SHOULD BE THE FUNCTIONS OF OMS? (check as many as you like)

_____Provide information for club members
_____Provide information for other modelers
_____Sponsor contests
_____Encourage association among members
_____Act as liaison with modeling press
_____Act as liaison with, and represent ornithopter builders to, the official modeling organizations
_____Other: ______________________

____

BASED ON YOUR ANSWERS TO THE PREVIOUS QUESTION, HOW WOULD YOU RATE THE EFFECTIVENESS OF OMS? _____GOOD _____FAIR _____POOR

WHY? ______________________

____

____

WOULD YOU BE INTERESTED IN HOLDING AN OMS OFFICE? _____YES _____NO

IF SO, WHICH ONE? _____PRESIDENT _____VICE PRESIDENT _____SECRETARY/TREASURER _____NEWSLETTER/PUBLICATIONS EDITOR

(check as many as you like... this places your name on the ballot)

PLEASE SEPARATE THIS SHEET AND SEND TO FRANK KIESER. MANY THANKS FOR YOUR HELP.

A NOTE ABOUT OUR LOGO AND OFFICIAL SEAL

At left is our official seal, which will soon make appearance wherever OMS rears its ugly head. The des one J. Philo Dandersnatch, wishes to make his artisti regarding the content of this seal known to us throug newsletter: "The central image is the now-familiar g powered ornithopter of Gustave Trouvé, which has long the masthead of Flapper Facts as the 'epitome of appl thinking' even though it is always printed there bass The Trouvé machine spreads its wings across a globe, ing the worldwide membership in OMS. Rising from the wings are a series of clipped lines, which are a grap resentation of the lively staccato of beating wings. can be darn sure that the Trouvé flapper could easily your socks off."

from: Patrick J. Deshaye
2349 W. Newton, #103
Seattle, WA 98199

SEATTLE WA 981 PM 8 JUN 1985

to: Roy & Shirley White
Rt. 1 Box 241
Catawissa, MO. 63015