Flapper Facts

Newsletter of the Ornithopter Modelers' Society

Issue #7 Summer 1994

Enter the Contest!

Don't forget to send in your ideas for variable-span ornithopters which fold their wings on the upstroke. Or, better yet, build one! Complete rules for the 1994 OMS Postal Contest were published in the Spring issue, or you can write and request a copy of the rules. There are still several months before the deadline, but remember, "Time flies faster than model ornithopters (G. Chaulet)"

New Address For the Summer

I will be in Florida until late August, and can be reached either at my old address or this new one. However, you will want to write to the new address to avoid delays.

Nathan Chronister
5311 Columbus Way S. #807
St. Petersburg, FL 33712 USA

Renewals and How To Join OMS

If your membership has expired, you will have to pay your dues right away to continue receiving Flapper Facts. I hope you will decide to extend your ornithopter adventure for another year. The cost is still $9, or $14 if you are outside the United States, made payable to Nathan Chronister. Don't miss the...

Next Issue:

I am planning a special biplane issue in order to make up for my previous neglect of that area. There will be many indoor plans and ideas, plus the article on P.H. Spencer's biplanes.

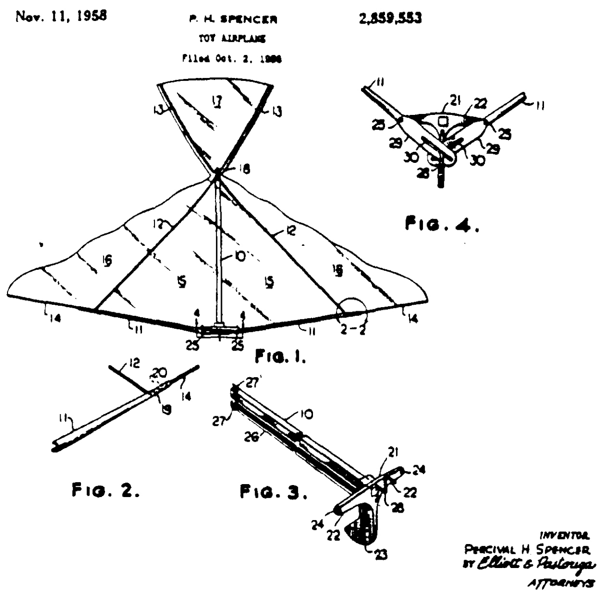
P. H. Spencer, ornithopter pioneer

The history of ornithopters is long, possibly beginning with an early simian ancestor of ours who was the first to dream of flying like a bird. The first designs were conceived by Leonardo da Vinci or someone before him less well recognized. And we all know about the long series of failed attempts at developing large, engine-driven ornithopters. What many people do not know is that the history of successful engine-driven ornithopters is quite long as well. Several flights are claimed between the years 1870 and 1940, but we do not have any evidence to prove that such claims are true. Then, in the 1950's, one man became very skilled at producing gas-powered ornithopters of every shape and size.

That man, Percival H. Spencer, probably had a greater mastery of engine-powered flappers than anyone before or since, and fortunately he filmed some of his creations in flight as a record of his accomplishments. Some of his flying machines still survive in museums and private collections, and one of them flew as recently as 1989. While complete details on the construction of Spence's ornithopters is not yet available, we are lucky to have a fairly detailed record of his work. (If you have any information or leads on other early engine-powered ornithopters, please right to the editor.)

Spence got the ornithopter bug in 1904, perhaps inspired by the Wrights' fixed-wing aircraft. Only 8 years old at that time, he raised pigeons as a hobby. Testifying to Spence's brilliant mind, he wired together some pigeon feathers, corks, and a rubber band to make a working ornithopter.

Spence also built full-size seaplanes. At age 13, he was towed aloft in a pontoon glider he built, and four years later he built and soloed his first powered airplane. Spence went on to design flying boats such as the Republic Seabee and the Spencer Aircar. In between, he had time for quite a bit of ornithopter research, which seems to have stretched from the 1930's until he founded Spencer Amphibian Aircar, Inc. in 1970.



Like many inventors of engine-powered ornithopters, Spence got his start with simple rubber-powered models. One of them landed on Igor Sikorsky's plate at a dinner. He patented his ornithopter in 1933, and received a second patent in 1958. The improved design included a flapping tail which contributed to propulsion and, it is said, stability. The mechanism for this tail flapping was quite simple and very clever. The wing braces (12, fig 1) simply extended through a slot to form the tail supports (13). As you can see, the flapping mechanism was slightly unconventional, but it was effective. Each wing lever had a slot in which the crank rotated. A ready-to-fly toy, complete with feather-printed wings, was marketed as the Wham-O Bird in the late 1950's, and about 865,000 were sold. They are now a collector's item.

I have seen a picture of Spence's first gas-powered ornithopter. It resembles a giant Wham-O Bird, and other than that I know very little about it. However, by the mid 1950's, the design had advanced considerably. Spence was using a bird-shaped fuselage and a flapping mechanism with connecting rods.

Actually, Spence built several of these seagull ornithopters in four different sizes. They were powered by .02, .049, .15, and .30 engines.

The .020 version had a 42 inch wingspan and weighed 19 ounces. That seems heavy for an ornithopter, I know, but it probably just shows what can be accomplished with the right gear ratio. Spence would begin by calculating the flapping loads on each new design, and would use this information to estimate the required gear ratio. After tests were made, he would then change the ratio if necessary so that the engine could run at the speed at which it is most powerful. With airplanes you adjust the prop size, with ornithopters, the gear ratio. The wings have to be roughly a certain size, so you can't adjust that to make up for the wrong gear ratio. (I've tried that with my own designs, and it doesn't work!)

Now everyone who wants to build gas-powered ornithopters will be wondering what magic number Spence used for his gear ratio. Unfortunately, the gearboxes on the existing seagull models are sealed, and the owners don't know exactly what is inside. I do have one scrap of information, though, which will allow us to solve the puzzle. The flapping rate of the .02 ornithopter was 440 CPM. Assuming that the engine was running at 20,000 RPM, which is close to its optimum speed, the gear ratio was about 45:1. Now you can go build your own seagull. I should add that every model will be a little different, depending on span, weight, and other factors. If there is a fixed wing area in your design, less reduction will be needed. Both engine and flapping speed decrease as model size increases, so the ratio might not change much with scale. Spence used steel spur gears in the seagulls.

The gearboxes were presumably sealed in order to provide a bath of lubricant. This is the system recommended by gear manufacturers for power-transmitting gears. This would also reduce the gear noise which is so loud in ornithopters. On the other hand, some of the commercial gearboxes for model airplanes get by without the sealed enclosure.

Other construction details: The .02 model had a plastic vacuum-formed

192 pages
of ornithopter information!

Flapper Facts has been in print since 1983. I didn't join until 1988, and when I was given a copy of the backissues, I was delighted by the vast amount of information they contained. It is a dream come true for any ornithopter enthusiast. Now, all of this and much more can be yours:

- Plans for over thirty different ornithopters
- In-depth discussion of optimum design parameters
- Detailed analysis of flapping mechanisms by Frank Kieser
- Indoor canard construction by Frank Kieser
- Ornithopter cartoons!
- Articles on all ornithopter topics
- Creative ideas from indoor to gas power

None of this can be found anywhere else! To get your copy as soon as possible, please send $19 ($24 outside the USA) to Nathan Chronister, 5311 Columbus Way S. #807, St. Petersburg, FL 33712. Your contribution will allow OMS to sponsor contests and publicity which will help us serve you better. Get ten years of newsletter for the cost of two years' membership dues!

And if that's not enough, get the Ornithopter Design Manual ($3), Vast Ornithopter Information Directory (newly expanded, $1.50), or Freebird easy-to-build ornithopter plans (2 stamps). The 42 page (5.5 x 8.5") Design Manual was written by Frank Kieser and basically tells (and shows) how to design and build ornithopters.

fuselage. Some of the larger seagulls had fiberglass bodies. Wing spars were birch with hard wire at the tip and as a diagonal brace. Later models used fiberglass spars. Clevis pins held the wings and con-rods in place: The wing pivots were mounted into the gearbox housing.

The seagulls were reliable, and many flights were made. Dale Anderson, a friend of Spence, wrote that the ornith-
opters had a lot of static thrust: "When engine peaked one must retain a firm grip or bird would fly out of the grasp ... The bird wanted to fly." A gentle release was all that was required to get the seagull flying. The smaller gulls could be flown in small areas using a fishing pole and reel. The line was attached to a dowel which protruded from the side of the fuselage. A slight pull caused the model to turn. They were usually flown without the tether, at some risk of escape.

Real seagulls once flew in formation with the noisy plastic one and even landed alongside it.

A big problem with gas-powered ornithopters is the landing. When the engine quits, the wings may be stuck in any position. Spence's designs kept the entire flapping cycle above the horizon so the wings never occupied an anhedral position. Therefore, the wings had to stop with a stabilizing dihedral, but it could be a large or small amount of dihedral, affecting the steepness of the glide. They usually stopped at the top of the wing stroke because the lift on the wings would turn the crank until this position was reached. Membrane wings have their disadvantages, so even when the mechanism locked at the bottom of the cycle, the glide was not very flat.

It has been suggested that the use of worm gears is dis-advantageous because it prevents the wings from rising to a dihedral position when the engine quits. This is not true, however, since as the seagulls demonstrate, the crank may stop at the dead-center position and therefore lock the wings in the down position even when spur gears are used. Electric ornithopters avoid this problem if a speed control is used.

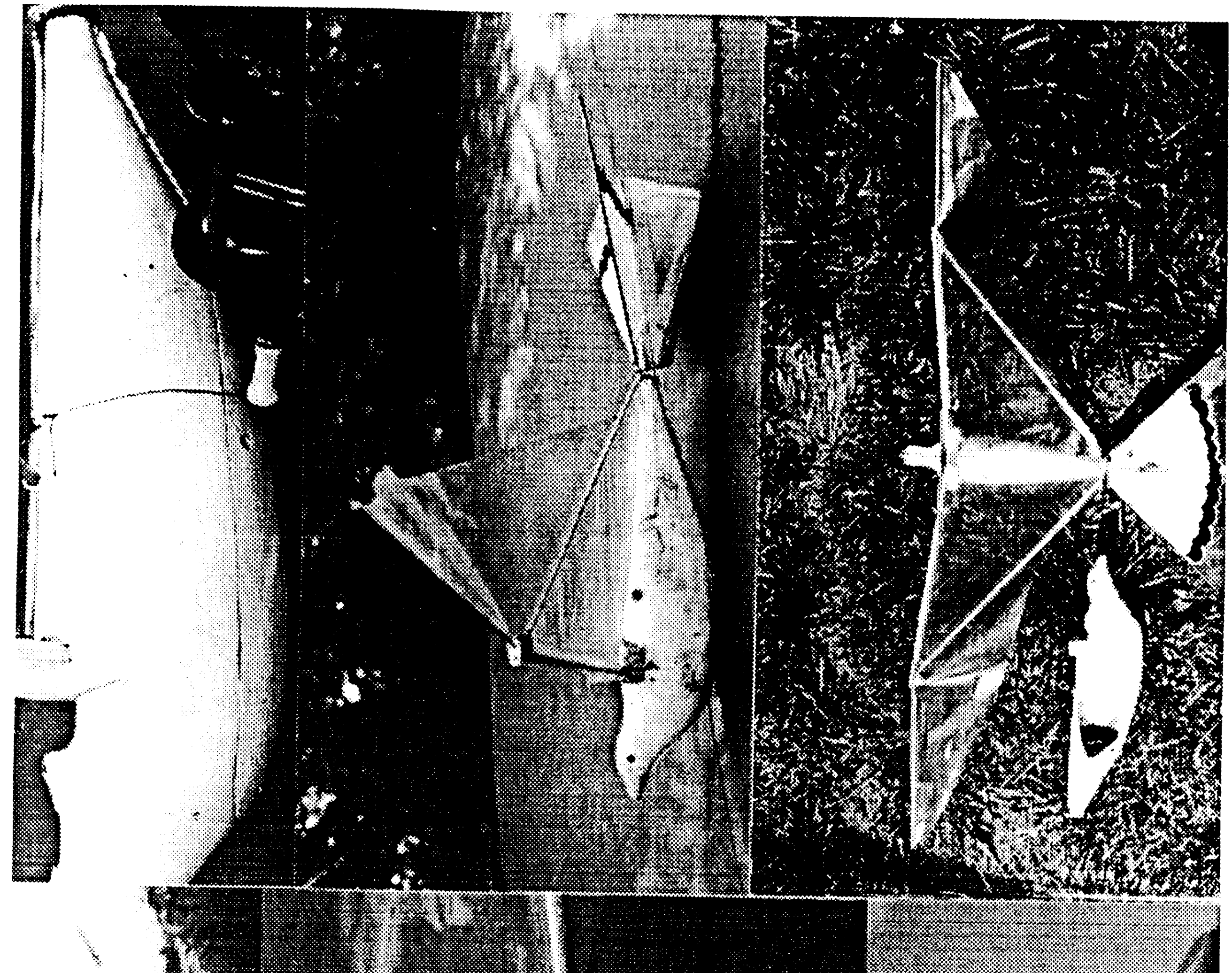
I had an opportunity to view a videotape of some flights of a larger seagull. It clearly performed as advertised. The rate of climb was very good, and its landings, though steep, were survived again and again.

The largest seagull spanned 8 feet and weighed 54 ounces. It was eventually given to one of Spence's friends who reportedly installed a radio in it. That model is now in the National Air and Space Museum.

The relative simplicity and great success of Spence's monoplanes should make them especially interesting to anyone wishing to build their own engine-powered ornithopters. Such a model could be produced as a kit (and Spence gave some consideration to that), or might be reproduced by anyone with access to custom-machined parts. Although plans are not available, I have attempted to provide all of the critical details in this article. I hope that this information will at least provide some inspiration and guidance.

Despite the great success of his monoplane ornithopters, Spence's greatest achievement was a radio-controlled biplane ornithopter built in the early 1960's. That project will be covered in the next issue of Flapper Facts. (NC)

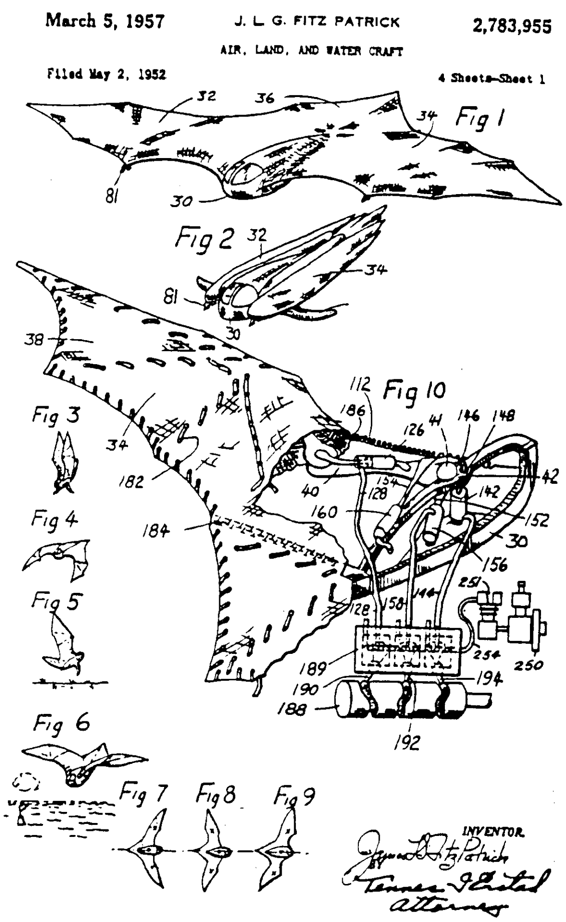
Photos (clockwise) 1. P.H. Spencer with one of his smaller seagulls. 2. The side of the plastic fuselage of an .020 powered model. 3. Side view. 4. Top view. 5. The upper holes on this tail plate were for the two bent rods which supported the tail and wings. When the wings flapped, the tail moved up and down. Bottom hole was for ventral fin. In the background, shows dowel to which tether was attached. 6. The flapping mechanism. The clear mylar wings in these pictures were replaced with painted mylar later in the project. A feather design was used, as can be seen on the tail. These photos were provided by Dale Anderson and Bill Warner. All except the first were taken recently by Anderson, and show the model he currently owns. (You can see the effects of age, and this ornithopter is no longer flyable.)



Full-Size Folding Wings

I keep saying that I know of no full-size, man-carrying ornithopter that achieved sustained flight. But I keep learning more about the various attempts that have been made, and sooner or later I'll probably be writing an article for this newsletter on some previously-unknown inventor who managed to solve the problem of the engine-driven man-carrier.

For now, all I can do is write about James L. C. Fitz Patrick's 1970's attempt to build a very complex, birdlike (or batlike) ornithopter. I am assuming it was not successful, but my sources were written before the machine was tested. (I am referring to a magazine article of unknown origin which I received through Sean Kinkade.)



Fitz Patrick's design ideas were taken directly from nature. His 1957 patent for an ornithopter looks much like a bat with a windshield instead of eyes. Even the landing gear is in the form of legs, not wheels. To reproduce the complex wing motions of the animal, Fitz Patrick decided to use pneumatic cylinders controlled by cams. These cylinders were to power a system of cables, springs, and structural members very similar to the muscles, tendons, and bones found in a bat's wing. In fact, the hinge surfaces on each structural member were patterned after bone joints since the shape of the joint determines the action of the wing. Simple hinges would not produce the same results.

Fitz Patrick used a rotating boom to test his theories on flapping flight. Hundreds of model wings were tested.

When built, Fitz Patrick's ornithopter weighed 320 pounds, was 6 feet long (no tail), and had a span of 40 feet with the sail cloth wings extended. Probably, a lot of practical simplifications were made in the 14 years between patent and production. Unfortunately, only one horsepower was provided to run the five compressed-air cylinders.

Fitz Patrick's ornithopter work was motivated, in part, by a desire to provide a STOL aircraft without the noise and fuel consumption of helicopters. Those who believe that birds' STOL abilities are simply a result of small size should observe that small model airplanes can't rise from a point-perch any better than full-size airplanes.

It is known that animals use less power in flight than existing ornithopters and most existing airplanes. Certainly a machine which successfully imitates their movements will be an efficient flyer as well. Many past attempts at full-size ornithopters imitated bird flight much more faithfully than small model ornithopters do.

It is difficult to find much information on past ornithopter attempts, and even the successful models of yesterday were scarcely publicized. I am forced to wonder, if any of the early man-carrying attempts had succeeded, would we even know about it? (NC)

Should flapper-propelled airplanes be allowed in the AMA ornithopter event?

These models are not true ornithopters because most of their lift is provided by fixed wings. Their flapping wings are large but contribute little lift as a result of the center of mass location. Current rules allow such entries, but many feel they should be excluded due to their reliance on fixed wings. Please write to the editor to express your views on this important issue.

An ornithopter model derives its propulsion solely from the flapping of its wing(s) or parts thereof. If part of a wing is fixed, the projected area of the flapping part shall not be less than the projected area of the fixed part, and the fixed part must not extend ahead of the leading edge or behind the trailing edge of the flapping parts. If the model has more than one wing, these restrictions apply independently to each wing, and the wings shall be substantially identical in size, shape, relative areas of fixed and flapping parts, and degree of flapping motion. The projected area of a flapping part is to be determined at a position midway between its extreme positions. No part of the horizontal stabilizing surface(s) shall be within a horizontal distance of one-fourth the wingspan from any part of a wing, and the total projected area of such surface(s) shall not exceed 50 percent of the total wing area. No protuberances or extensions of the fixed or flapping parts, which would satisfy the letter of these rules while violating their spirit or intent are permitted. Takeoff gear is not required. Twenty (20) seconds will define an official flight.

Those are the rules for the AMA ornithopter event. It seems that many of the rules are aimed at restricting the area and even the load carried by the fixed surfaces. Why else, for example, would the area of stabilizers and fixed parts of wings be limited, and why else would the stabilizer have to be away from the wing? Note, however, that the center of mass is often far from the flapping wings in an ornithopter, so that the one-fourth wingspan requirement falls far short of its intended goal. The fixed "stabilizer" can provide more lift than the flapping wings under these rules. Because the current rules do not successfully limit the amount of load carried by fixed wings, an infallible, yet easy-to-apply rule must be established in order to exclude all flapper-propelled airplanes from competition. (NC)

<u>What Is An Ornithopter?</u> by T. R. Quermann

Webster's dictionary defines ornithopter as "a heavier than air airplane deriving its chief support and propulsion from flapping wings."

The first sentence of the AMA rulebook description of an ornithopter says "An ornithopter model derives its propulsion solely from the flapping of its wing(s) or parts thereof." In addition, the last sentence of the general rules concerning Area of Supporting Surfaces says "projected area of horizontal stabilizing surface(s) in excess of 50 percent of the projected area of the supporting surface (wing area) shall be considered as wing area." Clearly the AMA rules equate wing and supporting surface. Thus both dictionary and AMA descriptions [by intent] require that the flapping wings of an ornithopter must provide both thrust and chief support.

In the Fall 1993 issue of OMS Flapper Facts, Sid Davidson presented a drawing of his ideas for a multiwing pusher design showing its general layout including center of gravity location. A rough sketch of this design with pertinent dimensions scaled from his drawing is shown in fig 1.

In order to balance in level flight, L1=.67W and L2=.33W. By supplying more than 2/3 of the support, the fixed forward surface must be considered

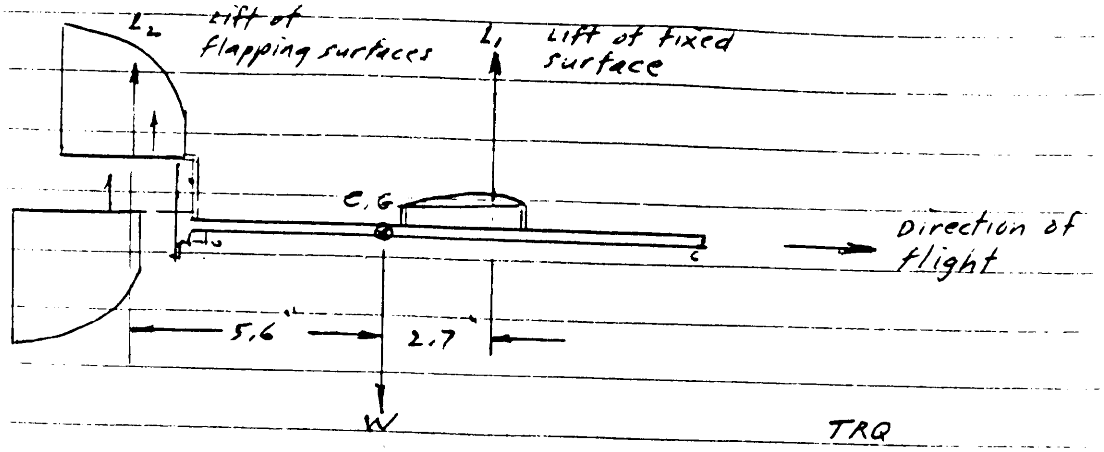


Fig 1 - Typical Pusher Design

the chief supporting surface or wing. Since it does not derive its support from its flapping wings, this machine is not an ornithopter. If it's not an ornithopter what is it? It's simply a tailless, heavier than air airplane stabilized and propelled by a multiplicity of large, single-bladed oscillating propellers [a flapper-propelled airplane].

If Sid's design is not an ornithopter, how can one account for the fact that very similar models have been accepted in competition and have established national records as ornithopters? Obviously the responsibility for meeting the rules starts with the model builder. The contest director must sign a record application form implying that he is satisfied that the performance meets all applicable AMA rules. In this connection, it is the contestant's responsibility to make sure that the C.D. processes the model or takes whatever steps are necessary to be able to sign the application in good conscience. Finally the AMA contest board must accept the record. In addition to the C.D. signed application, they are supplied with a three-view drawing of the model with all pertinent dimensions. Of all of the people involved, the only one who should be expected to know that the flapping wing of an ornithopter must supply most of the lift is the contestant, and obviously he is not going to tell the rest of them.

If the contestant doesn't know the rules either, then the problem must be that the rules are not stated explicitly enough. In order for Sid's model to qualify as a true ornithopter, its fixed surface would have to be moved forward more than six inches. A difference of this magnitude is as obvious as a 36-inch wingspan on an FID. The reason one is accepted and the other is not os that the FID rules specifically state a maximum wingspan while the ornithopter rules rely on the word wing previously equated to supporting surface and defined by Webster's Dictionary as "one of the airfoils that develop a major part of the lift which supports a heavier than air airplane" to indicate that the center of gravity must be significantly closer to the flapping surfaces than to the fixed horizontal surface.

Aside from the technicality of the definitions, what difference does the center of gravity make? Quite simply, a model with the majority of the load carried by a fixed wing will fly significantly better than one with the majority of the load carried by a flapping wing. The reason for this is that a typical wing flapping approximately up and down at a rate sufficient to propel a model can support only about 1/3 as much per unit area as a fixed wing with the same airfoil flying at the same speed. Thus the model supported by a flapping wing must fly faster than one supported by a fixed wing with only 1/2 the area. Since the power required in level flight is proportional to the cube of the velocity, the difference in performance is significant. If you don't believe the analysis, look at the demonstrated superior performance of the non-ornithopter pusher machines. Do you think you can match them with a true ornithopter?

I believe that most ornithopter buffs are attracted by the challenge of building a truly successful model that matches the approach evolved by nature. No one who has tried to build and fly an ornithopter can watch a bird or insect in flight without a tremendous amount of respect. For the AMA to demean this challenge by recognizing and rewarding designs that achieve their performance by ignoring one of the two basic characteristics of ornithopters is a disservice to all ornithopter modelers.

The AMA rules also include the statement "No part of the horizontal stabilizing surface(s) shall be within one-fourth the wingspan from any part of a wing." While this may seem innocent enough, it eliminates from competition any model built to an exact natural configuration! I know of no bird, insect, or bat that meets this requirement.

I think it is about time for the Ornithopter Modelers' Society (who else cares?) to formulate a reasonable set of rules for competition ornithopters and to sponsor a change in the AMA rules. Since this is a rules change year, any proposed changes must be submitted to the AMA by September 1st, or we must wait another two years.

As a starting point, my own suggestion is as follows:

An ornithopter model derives its chief support and sole propulsion from flapping wing(s) or parts thereof. If a part of a wing is fixed, the projected area of the fixed part shall be less than one third that of the flapping part. If the model has more than one wing, this restriction applies independently to each wing and the wings shall be substantially identical in size, shape, relative areas of fixed and flapping parts, and degree of flapping motion. The projected area of a flapping part is to be determined at a position midway between its extreme positions during the downstroke. If the model has a fixed horizontal stabilizer(s), in level flight the horizontal distance from the center of lift of the wing(s) to the center of gravity of the model shall not exceed one-third the horizontal distance from the center of lift of the wing(s) to the center of lift of the horizontal stabilizer(s). Takeoff gear is not required. Twenty seconds will define an official flight.

You will note that no mention is made of the size of the horizontal stabilizer. Its size doesn't matter, only the amount of load it carries is significant. A large surface carrying no load may be useful for stabilization but its drag is a detriment to performance.

I suggest that interested modelers read the current AMA rules for ornithopters, try to figure out what some of them mean and why they are there, and think about a better way to do it. I don't think there is much doubt that there is room for improvement. When was the last time you heard of a contest director rejecting a model because it violated the spirit or intent of a rule? (T.R. Quermann)

Quermann's proposed rule improves a lot on the current AMA rule, but even it has a loophole or two. By allowing the use of a fixed part of a flapping wing (a lifting, fixed center section), his proposal allows a configuration in which the fixed part of the wing has a higher angle of incidence than the flapping part and therefore provides a disproportionately large amount of lift. (Note that the flapping wings would produce little lift even at the same angle of incidence.) Also, there are some configurations in which a large fixed wing, placed near the center of the model, could produce a lot of lift without violating Quermann's rule. Another loophole is the possibility of slowly-flapping wings which act like fixed wings. These various loophole configurations are shown in figure 2.

Fortunately, it is possible to add a number of additional requirements to the proposed rule in order to specifically bar any of the loophole configurations mentioned above. By limiting the area of fixed, centrally-located surfaces, by preventing the use of tandem designs with a fixed

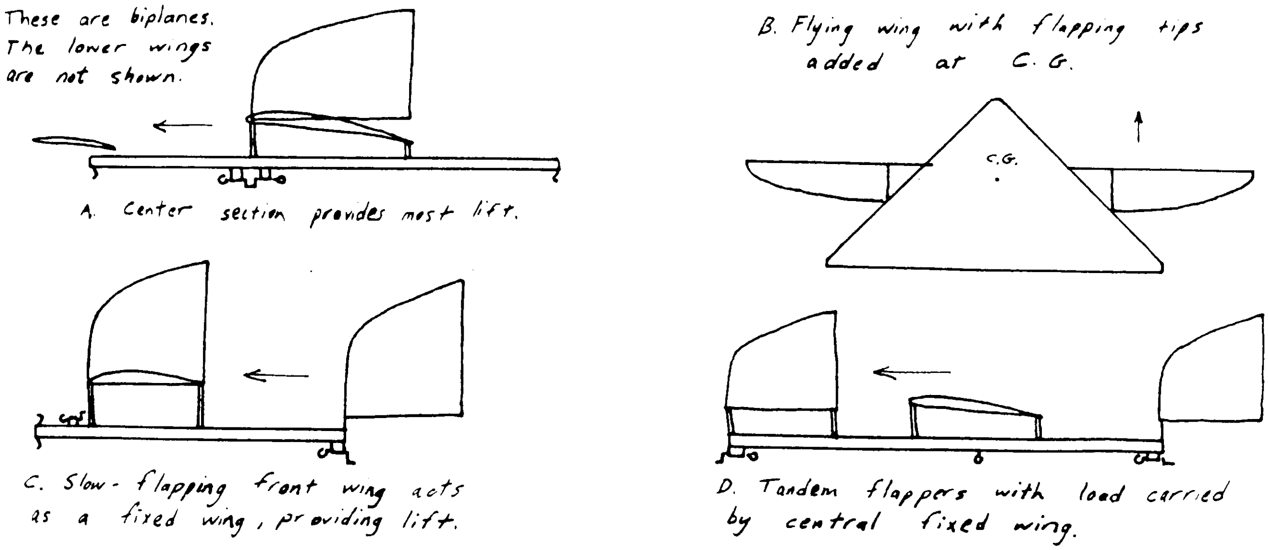


Fig 2 - Possible Loophole Designs

surface between the flapping wings, and by allowing only a minimal fixed center section, Quermann's second proposal accomplishes this. Although he has chosen to allow a small center section to avoid arguments about the projected area of structures such as the fuselage, this small fixed surface can produce a disproportionately large amount of lift. Since these are indoor models, I believe it would be reasonable to prohibit any fuselage which might act as a lifting surface, and to ignore the presence of any structural members between the wings which produce only drag. (NC)

An ornithopter model derives its chief support from its wing(s) and its sole propulsion from the flapping of its wing(s) or parts thereof. If a part of a wing is fixed, the projected area of the fixed part shall be less than 10 percent of the maximum projected area of the wing. If the model has more than one wing, this restriction applies independently to each wing, and the wings shall be substantially identical in size, shape, relative areas of fixed and flapping parts, and degree and rate of flapping motion. The model may have a single horizontal stabilizing surface, the projected area of which shall not exceed 50 percent of the maximum total projected wing area. In level flight the horizontal distance from the center of lift of the wing(s) to the center of gravity of the model shall not exceed one-third the horizontal distance from the center of lift of the wing(s) to the center of lift of the horizontal stabilizer(s). If the model has more than one wing, each wing shall be presumed to supply the same amount of lift, and the center of lift of the horizontal stabilizer shall not be located between the centers of lift of individual wings. Takeoff gear is not required. Twenty seconds will define an official flight. (T.R. Quermann)

The greatest problem with this rule is its complexity. We do not want to discourage people from participating in the contest my making the rules any more intimidating than they already are. In fact, it would be wonderful if we could simply require that the flapping wing(s) provide at least 3/4 of the lift. However, in many configurations, it is not possible to determine this, so more specific rules are required. Quermann's proposal is certainly more effective than the current rules and not significantly longer. If you feel you can do better, please send us your ideas. If you would like further justification for specific points in the above proposal, feel free to write to myself or T.R. Quermann, 7 Wyoming Drive, Huntington Station, NY 11746. We hope to reach a consensus as soon as possible so that a final proposal can be submitted to the AMA in time for the September 1st deadline. (NC)