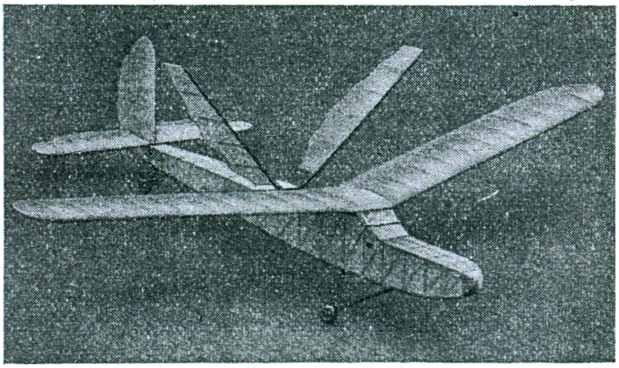
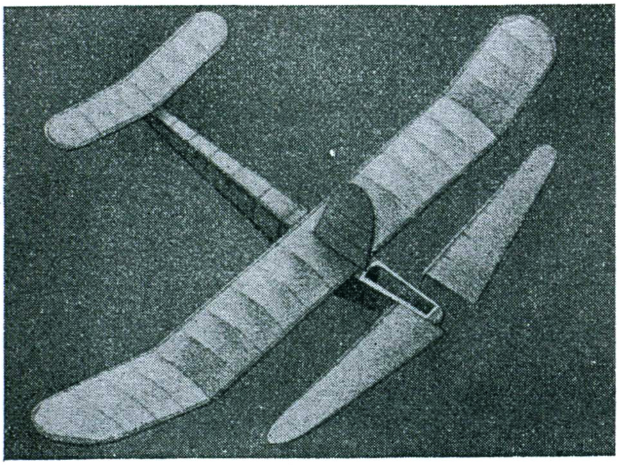
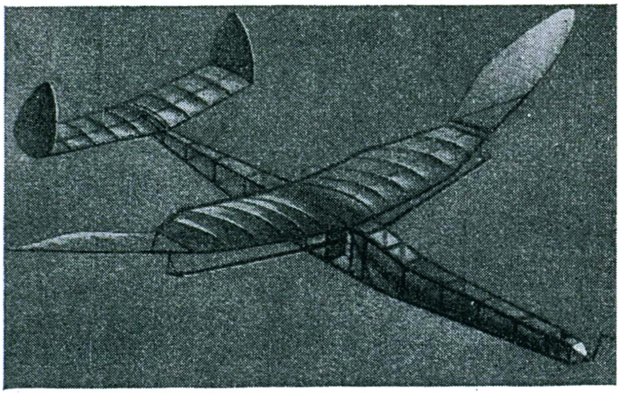
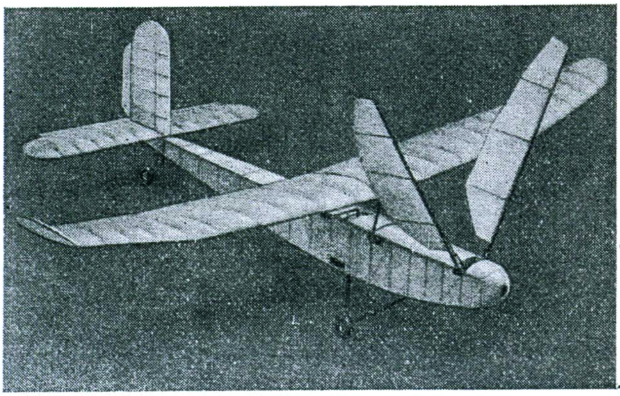








UNORTHODOX ORNITHOPTER

BY - - - - - - - -

FOR those who feel the urge to get right away from accepted ideas of flight and make experiments unhindered—consciously or otherwise—by thoughts of "conventional" design the ornithopter offers immense scope. The fact that no one has yet succeeded in producing a satisfactory man-carrying machine should be no deterrent to the modeller, and in any event is open to question as both American and German engineers claim to have achieved this end. Such pioneers as Leonardo da Vinci in Renaissance times, the Australian Hargrave and Penaud in the nineteenth century toyed with flapping flight and only in the present century was the formula abandoned by the majority of full-size designers in view of the progress made with screw-driven aircraft. Nevertheless it may well be argued that countless millions of birds with unlimited time for biological development have failed to improve upon flapping their wings as a means of aerial travel.

In case there are some who are not clear as to the exact definition of an ornithopter, it may be described as a flying machine that relies upon flapping of wings for its means of propulsion—in other words an aeroplane that flies like a bird. This definition is apt to lead the uninitiated astray, as any attempt exactly to imitate the motions of a bird's wing is doomed to disappointment. These movements are too complicated to be a practical possibility for the modeller if only on account of the weight of the cams and cranks involved. In the early stages of experiment at least it is essential to concentrate on a simple up and down wing movement.

Experimental Layouts.

Before proceeding to the design of a model it is as well to consider the choice of layouts available and their merits or otherwise. The first and most obvious choice is to build a wing that provides both lift and thrust—that is copy a bird layout. There is a saving of weight as no airscrew is required and the wing is performing natural functions. A number of successful models have been built to this formula but snags arise at once.

In the first place there is a period in each flap where the wings contribute little or no lift, and in order to make this period as short as possible rate of wing beats must be speeded up. This results in the fuselage frame oscillating in the opposite direction to the wing beats, and soon shakes a light structure to pieces. By strengthening the fuselage this can be overcome but only at the expense of weight, which requires yet stronger wing beats. A suitable compromise can be achieved, but flights are merely long enough to prove that the basic principle is sound. Such a model will fly for 20-30 seconds and climb perhaps ten to twelve feet in an R.O.G. flight, or up to fifty feet hand-launched, if carefully constructed to the lightest possible specification. Most models are too heavy and will only maintain the height at which they are launched.

Top: Ornithopter with flappers placed behind the mainplane. Practical disadvantages outweigh any theoretical gain in efficiency. Upper centre. Canard ornithopter with rear flapping pinions. This layout offers great promise and is worthy of further investigation. Lower centre: The American record holder, embodying flapping wing tips. Although considered inefficient it is simple to build and will certainly fly. Bottom: Petrol engined model developed at Rothenburgh—representing the present peak of model flapper progress.

MODELS No. 3

EXPERIMENTS

D. J. LAIDLAW-DICKSON

Present knowledge of flapping flight is not sufficient to progress much beyond this stage with the whole wing flapping. By embodying a rigid centre section, flights can be improved up to nearly a minute, which leads naturally to the next stage of development, a fixed main wing with only the tips actually flapping. Here there is enough fixed wing to provide lift at all times, while at the end of the power flight, irrespective of the final position of the flapping tips, the model has a reasonable glide. Such a design holds the American Ornithopter record.

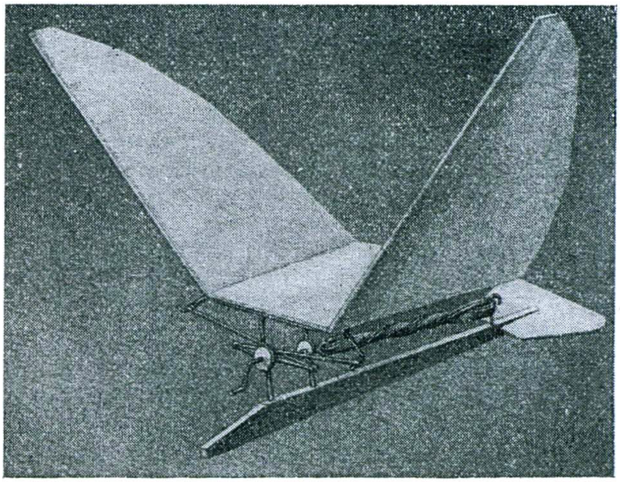
The next step is to divorce the flapping pinions entirely from the lifting wings, placing them in the position normally occupied by the airscrew. Results from such models carefully constructed are only slightly inferior to similar designs fitted with conventional propellers, the loss in performance being perhaps due to the extra weight of the cranking mechanism necessary to secure flapping flight. Care must be taken to secure the optimum lift of the mainplanes by putting them out of the disturbed air created by the flappers. This can be done by fitting gull wings or mounting them on a high pylon, so dear to American petrol modellers.

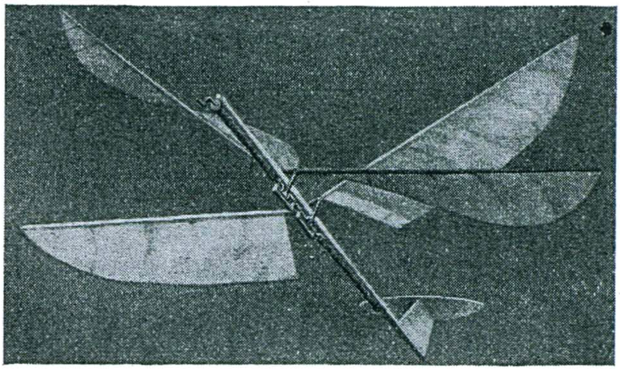
A further improvement can be effected by placing the flappers amidships behind the wing, while the theoretical ideal is to put them at the extreme rear and fly the ornithopter as a canard. No successful flights by this latter type are on record but durations of up to eleven minutes have been recorded for both front and amidships mounted flappers, driven by the usual rubber motor.

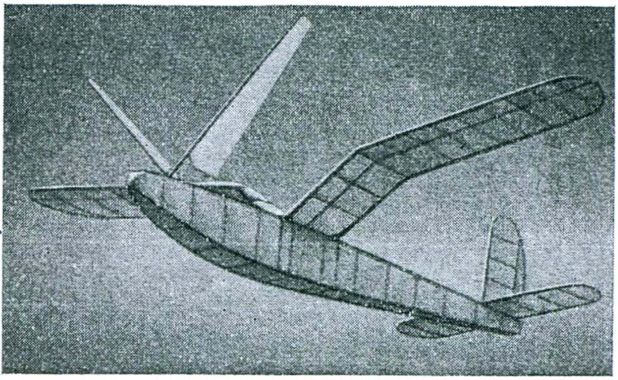
The ultimate aim is, of course, to build a petrol or diesel engined flapper, and very successful experiments took place under the guidance of Alexander Lippisch—designer of the Me 163—just prior to and during the early part of the war. The best recorded flight was made in 1943 with a 10 c.c. engine and exceeded thirty minutes. The power run was not stated, but in view of the height reached, estimated at about three hundred feet, could not have been less than twenty-five minutes at the most conservative estimate—without the aid of thermals, alleged to have been absent on this occasion. Other experiments at Rothenburg included the use of steam-driven ornithopters—though technical difficulties arose that rendered flights mediocre compared with those achieved by Lippisch's petrol models.

Rate of Flap.

Whatever the power unit the rate of flap necessary to maintain flight should be between 200 to 250 strokes per minute for average models. This should be the nett flapping speed after transmission losses and drag have been allowed for. In the case of petrol or diesel-driven models it will be necessary to fit a reduction gear of about 20 : 1—which gives comparatively slow but immensely powerful beats.







Top: "Slinn" flapper—an American commercial design introduced into this country by Mr. F. C. Camm. A good primary type. Upper centre: An indoor flapper that is unusual in possessing an undercarriage. R.O.G. is possible if weight is kept down to 1 oz. Lower centre: A remarkable effort with two pairs of wings in tandem, similar to those designed by Dr. Holst, though employing conventional drive. Bottom: "Libelle" by Alexander Lippisch, well-known German full-size designer. Probably the most successful rubber-driven ornithopter.

Apart from the power, the rate of beat is governed by the area of the wings and their elasticity. Generally, large models fly better with slow powerful beats of 200-220 per minute, while slow indoor models may require as much as 400 strokes per minute. Taking a bird analogy we can compare the slow wing beats of a stork with those of the tiny humming bird, which move faster than the eye can follow.

Design of Flapping Pinions.

Flapping wings should be approximately one quarter the area of the fixed lifting surfaces, and built as lightly as possible, as increased weight means more power and greater difficulty in control.

A successful flapping pinion is the one essential of a good ornithopter and requires special care. It is necessary for the leading edge spar to be rigid both in an up and down direction and fore and aft. If it bends under load it will lose propulsive efficiency. The surface of the pinion on the other hand must be capable of being warped, that is to say the trailing edge must be flexible rather like the wing of an early Wright biplane. The wing must be sufficiently elastic to reverse the direction of warping, when changing from the downstroke to the upstroke. The slower the rate of flapping the greater flexibility is required, while for faster wing beats it must be correspondingly stiffer. Speed of flight and incidence of the wing also govern flexibility.

Suitable materials for use in flapping pinions include bamboo, cane and spruce. They should be of half round section, hollowed out to give the required torsional flexibility. For petrol-driven models dural sections stiffened by dowelling might be employed. Larger models require wing ribs for which bamboo is most suitable. Covering may be bamboo paper, silk, or in the case of very light models ordinary tissue. A non-shrinking dope such as banana oil should be used. At all times bear in mind that given sufficient strength the lightest possible material should be used. Blue draughtsman's linen in its natural state has also been utilised.

Transmission of Power.

A direct drive is usual in the case of rubber-driven models, though models have been built with geared drive. This adds to the weight and is not generally necessary. If it is desired to secure an unusually long power run it may be embodied. The location of motors is as in normal rubber-powered models. Size for size the amount of strands should be the same as for a high performance contest duration model.

Where a petrol engine is installed, as stated above, reduction gears of up to 20 : 1 will be necessary. It will also probably be found desirable to install some supplementary cooling device such as a fan to prevent overheating. As yet there have been no reports of a diesel engined ornithopter, but this would seem to be the ideal motive power, as in addition to light weight and trouble free operation, it would require no special cooling arrangements.

Having decided on the power unit the next problem is that of transmitting it to the flapping pinions. For this purpose a two-throw crankshaft is employed, from which extend connecting rods to the flapping pinions. The greatest possible accuracy is necessary in making these components, and it is worth while constructing a simple jig. For rubber-driven models 18 s.w.g. is a suitable material, bent from straight lengths.

Where petrol or diesel-engined power units are involved weight will allow for machining really accurate crankshafts and con-rods from dural—in which case none of this trouble need be experienced.

Unusual Approach.

So far the ornithopter has been discussed from the more usual angles—that is if so unconventional a type can ever be so approached. A number of experimenters have tackled it by forgetting everything they knew about normal drives and starting right from the very beginning. Hargrave, for example, had the pioneer advantage that there was little to forget, and his drive is of interest to us to-day in that it embodied *stretched* rubber band instead of *twisted* strands. His method was to stretch his rubber and in the stretched state wind it on to a wooden roller, tethering the last end to a point on the fuselage. This caused the roller to unwind furiously, thus flapping the wings which were attached to an eye piece at each end of the roller. This roller, it should be added, was attached at right angles to the fuselage, and so avoided any necessity for changing the direction of the unwinding, or the need for any crank motion. Furthermore, this gave his wings that forwards and backwards sweep more nearly approximating bird flight than later designs. A similar method was used forty years later by the German Dr. Von Holst. His method consisted of two conical spools, driven by an elastic motor, on which thin cord was wound. As the motor unwound it reeled back the cord on to an eccentrically-mounted "tumbler plate," coupled to the wings, flapping them regularly as it rotated about its own longitudinal axis.

Some of the petrol-engined ornithopters are marvels of ingenuity, with cunning bevel-geared drives to the flapping pinions. One such example has the pinion leading edge swept back at 45 degrees, a simple open worm gear drive connected to the engine crankshaft by a stout rubber tube, and having starter engaging dogs in front to facilitate swinging over on starting. The seepback of the leading edge enables an eccentric forward and backwards flight path to be taken by the pinion, and resulted in heights of several hundred feet being obtained on a number of occasions. Bevel and worm gears have also been used on rubber-driven models, but generally the need for precision work rules them out unless the experimeter is lucky enough to possess a lathe or excellent workshop facilities.

Another curious design made use of the fixed centre section of the wing to house the rubber motor driving the flappers, disposed outboard of the centre section. This again made use of the old Hargrave principle of drive in line with the motion, that is at right angles to the flight path of the model. Apart from placing an undesirably large proportion of the weight away from the centre of the model, leading to difficulty in controlling the pitching moment, this seems one of the most practical and least "gadget-y" of the ornithopter solutions.

Continuing Research.

It is hoped this brief summary of ornithopter research will set readers thinking and perhaps produce one or two oddities in time for exhibition at Dorland Hall this year. Contrary to our usual custom we have not concluded with plans of a successful ornithopter built and tested by our Research Staff because at the moment the models built are still in the development stage. Do not be despondent—they do fly—and fly quite well, but they remain very much the spoilt children of their designers, they will not do their tricks without coaxing. When we have developed a trouble-free flapper that can be confidently expected to perform even with a trifle of careless building then it will be presented to our readers.