THE BEST SHAPES FOR WINGS.

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THE results which we reach by practical flying experiments will depend most of all upon the shapes which we give to the wings used in experimenting.

Therefore there is probably no more important subject in the technics of flying than that which refers to wing formation.

The primitive idea that the desired effects could be produced by means of flat wings has now been abandoned, for we know that the curvature of birds' wings gives extraordinary advantages in flying.

The experiments on the resistance of air to curved surfaces have shown that even very slight curvatures of the wing-profile increase considerably the sustaining power, and thereby diminish the amount of power required in flight.

The wing of a bird is excellent not only because of the curvature of its cross-section, but the rest of its structure and formation also has influence upon the flight. Therefore the outline of the wing is certainly of importance.

It is probable that the form of the cross-section of the wing and flight-feathers (*Schwungfedern*) has a favorable influence upon the flight.

Experiments have not yet been made to show conclusively whether or not the feather structure of a wing endows it with a special quality whereby the sustaining power is increased. With investigators this has been a subject of conjecture. Therefore it is questionable (*auch fraglich*) whether we are wrong if, in constructing flying apparatus, we keep to the bat's wing, which is easier to construct.

Bats fly much better than is generally thought. Two early bats, which I saw flying this summer in broad sunshine and in somewhat windy weather, sailed along so well without flapping their wings that I thought, at first, they were swallows. Of course on evenings when there is no wind, the bat must flutter continually. The early-flying bat is also called evening-sailer (*Abendsegler*) which indicates that its sailing flight has been marked.

The most important point as regards the form of the wing will always be the curvature of its profile. If we examine any bird's wing we find that the enclosed bones cause a decided thickening at the forward edge. The question now is, What part does this thickening play in the action of the curved surface? The thickening is quite considerable, particularly in birds which have long, narrow wings. An albatross in my possession has a breadth of wing 16 centimetres, the thickened part of which measures 2 centimetres; the thickness is therefore $\frac{1}{8}$ of the breadth of the wing. As the albatross is one of the best sailers, we can scarcely assume that the comparatively great thickness of the wing at its outer edge has a detrimental effect upon the bird's flight.

For a long time I have assumed that the thickening which all birds' wings have at the front edge produces a favorable effect in sailing flight.

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By means of free-sailing models I have now learned that nature makes a virtue of necessity, that the thickened front edge is not only harmless, but in sailing flight is helpful (*sondern den Schwebe-effect nicht unerheblich erhöht*).

The experiments are easily tried. It is only necessary to make a number of models of equal size and weight, each one having a different curve in its sustaining surfaces. These models I make of strong drawing paper, the size of the surfaces being about 4 inches in width by 20 inches in length.[1]

The experimenter can let these models sail from any tower or roof in front of which there is an open space. Each model must be made to glide through the air many times until it

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[1] Drawings of these models will be found on pp. 14 and 15, Aeronautical Annual, No. 2.

reaches the ground. Experiments must be made in the stillest possible air.

The lengths of flights are all nöted down, and from a long series of experiments the arithmetical mean for each design is computed. The models having the best profiles will make the longest flights. In this way a reliable table can be made which will show the relative merits of the profiles, and will also show quite plainly in which direction the most useful form will have to be developed.

Until now I have endeavored to find out the best proportions for wings by constructing different kinds of sailing apparatus. In this way, of course, many important facts have been ascertained. The construction of full-sized apparatus requires a great deal of time and is expensive, therefore we must welcome a method which permits inquiry into the forms of wings in models which fly automatically. Besides that, it is not every one's business to throw himself into space in a sailing apparatus, although he who would succeed in practical flying can scarcely avoid this way.

Considering the fact that the most important thing is to ascertain what are the best qualities of the natural wing, — which is in every respect perfect, — these steadily sailing models offer every one an opportunity of engaging in experiments of this kind. Further, any one who takes up this kind of experiment will find great pleasure in watching the manœuvres of his small flyers, which often vie with the best sailers among birds. I can therefore recommend this occupation not only for the furthering of the science of mechanical flight, but also because it affords a most interesting pastime.

The few measurements made so far by this method are too incomplete to be fit, as yet, for publication. I am preparing, however, a systematic series of experiments, the results of which will be stated when the experiments are finished.

Meanwhile, I cherish the hope that this paper may be an incentive to others to make similar experiments, so that we may sooner reach the desired end.

NOTE. — This is a part of Lilienthal's unfinished work, which it is to be hoped will be taken up by many. The fact that he thought it well worth doing is significant. — ED.