Soaring flight.

By E. C. Kuffaker

CK

In response to your suggestion that I embody in small compass the leading features of the paper recently placed in your hands upon the "Value of Curved Surfaces in Flight" I beg to submit the following abstract.

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Observation

The form of the wing in flight differs greatly from that of the same wing at rest. So much so that the most careful and accurate measurments

of various sections of the wing at rest not only leave us in doubt as to the true form of the wing in flight but may lead to erroneous conclusions in regard to the philosophy of flight. And since there is no known method by which the form of the wing in flight may be accurately determined we are forced to rely upon the testimony of the eye alone for our knowledge. All our observations are therefore attended with a certain degree of uncertainty, and any near approach to the truth can be made only by means of countless observations, by numerous and conscientious observers, who are able to divest their minds of all preconceived notions of the philosophy of flight.

The typical wing in soaring flight is not a screw but a shield, with sharp curvature near the leading edge, whose rear margin follows close upon the path of the front margin. In swift flight the rear margin of the secondaries portion are usually more elevated than the front margin. The wing therfore does not act as an inclined, but as a horizontal surface, along whose front margin the air is invariably deflected upward, not downward.

The following facts are to be accounted for in the flight of such soaring birds as the common vulture, or buzzard: 1st. The bird may fly to any distance, or rise to any desired altitude without flapping the wings - 2nd It flaps

the wings only when near the earth. never at great altitudes. – 3rd Straight forward flight is usually a descending flight. though instances are not rare in which horizontal flight is maintained for a distance of from 1000 to 2000 ft.
4th Such flight is often maintained without perceptible motion of the wings. and when horizontal is accomplished with a low and uniform velocity.
5th A slight rocking motion enables the bird to maintain its elevation indefinately; during these rocking movments. the eye cannot detect any marked elevation of the rear margins. 6th In soaring in a horizontal plane. the path of the bird is usually elliptical. and it will be found. that. the bird increases its velocity only as the degree of curvature increases. 7th In ascending the

ascent is most rapid when the projection of the path is an incurving spiral. 8th While the bird often ascends uniformly and rapidly it more commonly rises and falls alternately, plunging downward from the highest point obtained often to a distance of many feet. 9th In descending and rising along a vertical curve, the bird adds to its velocity without motion of the wings. 10th In its uniform rapid ascents, no rocking motion can be detected, nor can the eye determine with certainty when the rear margin of the wing lies within and when without the path of the front margin. 11th I have known the buzzard to rise 500 ft in two minutes, and to make short ascents far more rapidly. 12th The bird may often be seen upon a stormy

day to stand absolutely motionless in the face of a high wind for many seconds. neither advancing nor receding, neither rising or falling. 13th. When contending with a high wind the bird never flaps its wings. When its advance has been checked by the violence of the wind, it will move forward again when the violence has abated. the only motion discernible being a slow depression of the wings. 14th. When stopped by the wind it will often turn upon a short curve, and outstrip the wind; and when thus flying before the wind, it can turn and stop instantly over any point upon the Earth's surface. 15th We are not justified in assuming the existance of aerial currents to account for the flight of the soaring birds. since

they soar with perfect success in deep valleys, near the earth and through timbered regions, where not the slightest breath of air is stirring. They soar equally well also at great altitudes, where it is not easy to account for the existence of differential currents. Again the most rapid ascent I have ever witnessed, was that of a buzzard along the face of a perpendicular cliff in a still atmosphere. The ascent was made upon a corkscrew of small diameter, and it seems more plausible to attribute some virtue to the path of its ascent than to assume the existence of currents, of which we have no evidence whatever. Any conclusions in regard to the existence of

arrial currents which we may reach from a considration of the irregular flight of the buzzard, are rendered questionable by the steady flight and the rapid rise of the black vulture. a bird which should perhaps rank first among the soaring birds. 16th The soaring birds never drift with the wind, nor cease to move forward, so long as they remain in the air. their movements being in large degree Automatic.

It will be seen that the problem of soaring flight involves these subordinate problems: 1st An explanation of the well ascertained fact that the bird may remain motionless for a number of seconds in the face of a high wind, or sail horizontally in a calm atmosphere, long distances, with no perceptible

movement of either body or wings. 2nd We are to account for the manner in which the bird obtains a powerful reaction from the air, in a forward direction, by the slow movements of a surface lying parallel to the direction of flight. This, the most difficult of the problems of flight, can hardly be explained the assumption of arrial currents. The statement that the soaring birds rise to incredible heights on motionless wings is altogether false and misleading. The bird rises without flapping, but never without a movement of some sort. The marvel is that it rises by means of movements so slow and measured. In general it may be said that the bird adds to its velocity in ascending only along

lines of increasing curvature. 3rd. A satisfactory and full explanation of automic flight. Upon the solution of this problem finally depends the success of artificial flight. Upon this solution depends the all important question of safety.

Experiment.

In order if possible to reproduce the flight of soaring birds artificially I have constructed a small model shown in fig I. This model consists of a spar of light red cedar. 3 fut in length, and originally 1" x 3/4" in cross-section, but bended upon the upper front margin and hollowed out underneath to resemble the front margin of the wing of a bird.

Two umbrella stays. 8 inches in length, passed through the extremity of the spar. and are slightly curved. to correspond to the curvature of a wing. Their free extremities are connected by a violin string. tightly drawn. The whole is covered by black satin. nowhere tightly drawn. except near the spar. The wing thus formed is concave beneath. and convex above. the curvature being greater near the leading edge. and is attached at its middle point to a block of oak. 2"x2"x5"; loaded with lead. A rudder. made of light white pine. and supporting. by means of a wire. a tightly drawn sail. of one square foot of surface. is attached to the block of oak. in such a way that the plane of the rudder exactly coincides with

the plane of the violin string and the leading lower edge of the spar.

The center of gravity lies within the block of oak midway of the wing. the rudder extending 2 feet behind the wing. The surface of the wing amounts to 2 square feet. The model when loaded with 1½ pounds of lead weighs 2 pounds.

The results accomplished with this rough model are in many respects remarkable. When lightly thrust from the hand, it sails away in a truly straight line and with an easy and steady flight, in striking contrast with that of an inclined plane similarly mounted. The flight is in all respects similar to that of the soaring birds when descending along a gradient

of 1 in 15. The velocity attained has usually been about 25 feet per second, or 17 miles per hour. I have obtained short horizontal flights with a smaller velocity. If thrust rapidly forward, the model rises to a height of 8 or 10 feet, when, hanging suspended for a moment, it sails forward to the ground. Having attached a vertical rudder, I exposed it to the mercy of a high and boisterous wind. Under the action of a strong and steady breeze, it rises to a height of 12 or 15 feet, slowly retreating from the wind, but always facing it. Having reached a certain height it invariably begins a descent into the face of the wind. This action is precisely that

of the soaring birds in facing a strong wind; and it has a most important bearing upon the question of artificial flight, showing, as it does that an air-ship may be so constructed as to rise in a high wind, and return to the spot from which it arose, without danger to an aeronaut. Even in an irregular and stormy wind, the model is not over-turned, but faces about quickly under the actions of the rudder.

I next tried the effect of exposing the model to the action of a steady wind blowing at the rate of perhaps 30 miles an hour, or 45 feet per second, at the same time keeping it stationary by holding it at arm's length

overhead. Two fingers were laid directly above the center of gravity, so that the action of the horizontal rudder kept the wing always parallel to the current. Not only did the wind support the weight of the model so that it rocked easily back and forth beneath the fingers, but when the wind was high, it produced an upward pull, which could not have been less than two pounds additional. So that with a velocity of certainly not more than 35 miles per hour, the model supported time and again a weight of 4 pounds or two pounds to each square foot of sustaining surface - not counting the rudder, which had only its own small weight to support.

Nor did this upward pull occur momentarily, but was strongest when the wind was steadiest and the model stationary. While nothing better has I think been recorded of the lifting power of a model the small amount of power required to hold it against the wind, was not less remarkable. So slight was it, that the model rocked back and forth easily, and the resistance apparently decreased with the velocity of the wind.

I repeatedly tried the effect of pulling the model downward, and in every instance it was driven forward into the wind, reproducing again the effect of the slight wing movements of the bird. (omission)

Success with such a model depends largely

upon the concentration of weight near the center of gravity, with the employment of very light wings and rudder. But with the materials at my disposal, I have not been able to construct a model capable of testing thoroughly the principles involved. A few pieces of fish hook steel wire, well tempered, are all that is necessary to the making of a suitable model. But these I have not as yet succeeded in obtaining.

Fig 2. represents a better form made of nos. 16 and 20 fish hook ~~wire~~ steel, than that which I have used. With my present model a flight of 300 feet is the best I have obtained.

omission in Huffaker's paper.

The longest flight I have thus far succeeded in obtaining was 300 f. But considering that the materials at my disposal were of inferior character, much better results could hardly have been expected — Fig 2 illustrates a model which should give far better results.

Theory.

In the light of recent investigations, made by numerous observers and experimenters, the explanation of flight upon the long accepted theory of an inclined plane, wedged forward upon the air, is no longer tenable. A new theory is demanded, and it is to be hoped, one will be found which will promise better results in the field of artificial flight. It has long been known that a fluid flowing through a tube of varying section exerts a pressure which is inversely proportional to the cross section of the tube, and it has occurred to me, that this principle

might be applied to the solution of the problem of flight. Thus, if the wing of a bird be so placed in a strong current of air that the plane of its margins shall lie in the direction of the current, the under surface being concave will furnish the condition of increased pressure, the remaining sides of the tube being formed by the moving mass of the surrounding air. The strams which enter the concave surface, and those immediately beneath, have their cross-sections enlarged, and consequently suffer, in accordance with well established principles, a loss of velocity, and a transformation of the energy of the moving mass into pressure. This increased pressure upon the concave

surface is exerted equally in all directions.
so that the for and aft. pressures are
balanced. The reverse of this takes place
upon the upper convex surface. where the
velocity is increased, and the pressure
diminished. The surface may therefore
be sustained in a horizontal position.
while encountering no resistance from the
sustaining surface. That the bird is
thus sustained in the face of a high wind
can no longer be questioned. If this theory
be correct, there is no necessity for assuming
the existance of arrial currents. The
solution of the second problem. the ascent
of the soaring birds. which is unquestionably
the most difficult connected with the subject.

can also. I think, be explained without the assumption of aerial currents. I find that the ascent of these birds is accompanied by certain well defined movements, and while pursuing certain courses, and I have never known a bird to rise without such movements, nor along any other lines of ascent. My contention is therefore, that we are to look to these movements and to these curves for the explanation of their flight. And that those slow and measured movements, which observers have either overlooked, or regarded as the means of guidance, are in reality, the powerful wing strokes, by which the bird climbs into the heavens. I wish to emphasize

the important fact that these nervous strokes are:- 1st Slow and scarcely at times noticable, and 2nd that the wing is in all cases approximately parallel to the line of flight. The explanation is to be found in the peculiar form of the wing, and its action in modifying the course of the stream lines.

The strong winged birds by soaring perform feats of strength and endurance which they could never accomplish by flapping. We may regard soaring therefore as the highest attainable perfection in the evolution of flight. The question arises, why may we not learn a lesson from the birds, and attempt the accomplishment of artificial flight by soaring. None of the difficulties to be encountered in reproducing flapping

flight are to be met with. and the chief objection to the use of the screw propeller, the necessity for rapid motion, would be avoided.

It is to be remembered that in regard to the advantages of soaring flight, we experimentally are in absolute ignorance.

And it is conceivable that further investigations and experiments along this line, may disclose the fact that artificial flight is by no means so difficult as we have been led to believe. Fig 3. represents a form of soaring machine by which the principal movments of the soaring birds may be reproduced.

Yours respectfully

(Signed) E.C. Huffaker

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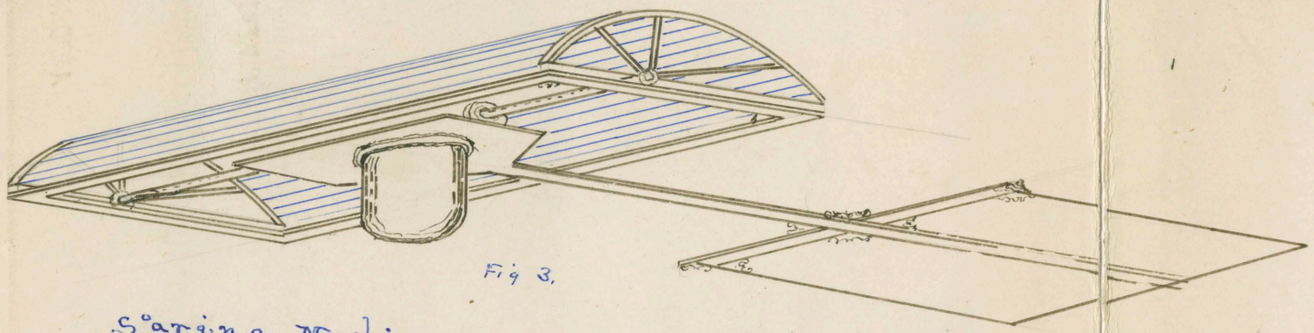


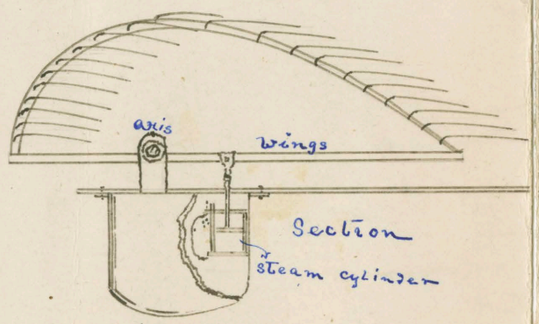
Fig 3.

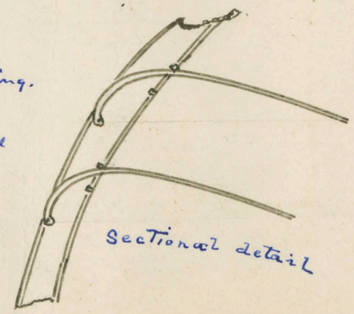
Soaring Machine

Wing frame - 20' x 10' x 5'.
Number of wings. 25'
Expanse of wing 20'
width " " 18"
depth " " "

Total Sustaining Surface 750 square feet.
Stroke of piston 6".
Number of strokes per minute 50.
Wings are all parallel.
Action of wings similar and reverse-
ing The slow wing stroke of the soaring birds.
The ~~total~~ surface as a whole also acts as a wing.
Horse Power required = $\frac{\text{total weight}}{550 \text{ lbs.} \times \text{desired rate of vertical ascent per second.}}$

Materials - Wing frame and rudder aluminum.
remainder of frame steel.
Wings - Canvas, ribbed with ~~wood~~
fish hook steel wire; margin
strengthened with piano wire.
rudder ~~is~~ Canvas.
Weight Carried. At 25 miles per hour 1000 lbs.
" 35 " " " 2000 "
Estimates based upon the flight of the
vultures.





Sectional detail

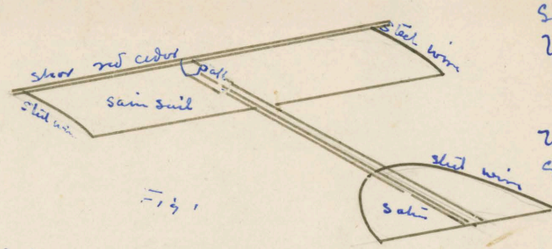


Fig 1.

Sustaining surface 2 sq ft:
Weight - 25 mi. per hr. 2 lbs.
" - 35 mi per hr. 4 lbs.
Width of wing 8"
Expanse " " 8'
Depth of camber - $\frac{3}{4}$"
Plane of front ~~edge~~
margin parallel to rudder.

Model used in ~~soaring~~ experiments.

r rudder r

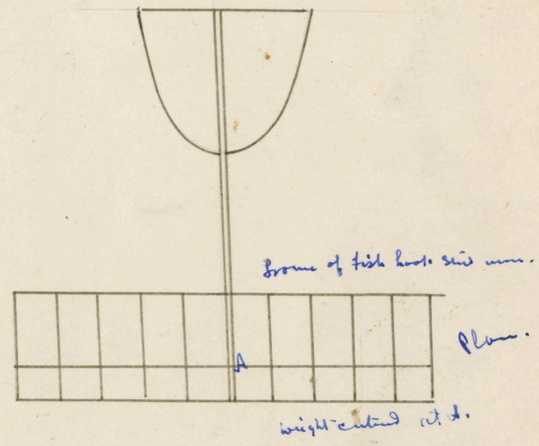
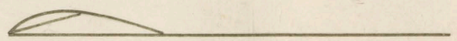


Fig 2.

Improved Model.



Section

Plane of front & rear margin
parallel to rudder.

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