# A COMPARISON OF THE PERFORMANCES OF A VULTURE AND OF A "TERN" SAILPLANE.

By T. G. NYBORG.

In THE SAILPLANE of May 17th there is a very interesting article by "Kentigern" on the estimation of the performance of a vulture from data supplied by Mr. S. M. Vine of South Africa.

"Kentigern" states that Professor Melville Jones has shown that the dynamic resistance of a streamlined body is negligible compared to the skin friction. I rather disagree with this theory, as I consider that the skin friction and dynamic resistance of a body with elevator and rudder should be alike to make the total resistance a minimum for the body. This, of course, is not always obtained, as there are other considerations which govern the body design, as may be seen from the many different forms of birds' bodies (e.g., compare the body of a pheasant with that of a gull).

The body of a bird of prey we would expect to be fairly well streamlined, but the vulture scarcely comes into this category, and we must look to its mode of living and the conditions under which it has to start its flight, as it is upon those factors that the design of the wings and body mainly depends.

From the data given by Mr. Vine, I would imagine that the vulture has to rise off the ground under restricted conditions and it would be of interest to know if the particular vulture had a good feed shortly before it was shot. I am inclined to think it had.

As a rule, vultures object to heavy weather or very gusty winds, and prefer to get down when such conditions prevail. I was told by a friend that he had once observed a vulture in Chile being tossed about for a considerable time before it succeeded in making shelter, although seagulls were flying about as usual with no indication of difficulty. If I remember rightly, an article appeared in *Flight* some years ago describing how an aeroplane pilot hunted vultures in Africa and their maximum speed was then given as 50-55 m.p.h.

Unfortunately, I am not familiar with the actual shape and dimensions of a vulture's body, but from photographs it appears to be rather short or egg-shaped and not exactly well streamlined. I am, therefore, of the opinion that the dynamic resistance of the body cannot be neglected. In fact, I think that it amounts to more than the frictional resistance due to the body surface which "Kentigern" has taken as 32 sq. ft., whereas I reckon about 5 sq. ft.

With regard to the modern glider, say the TERN, I quite agree that the dynamic resistance may be neglected, as it only amounts to 10 per cent. or even less of the skin friction.

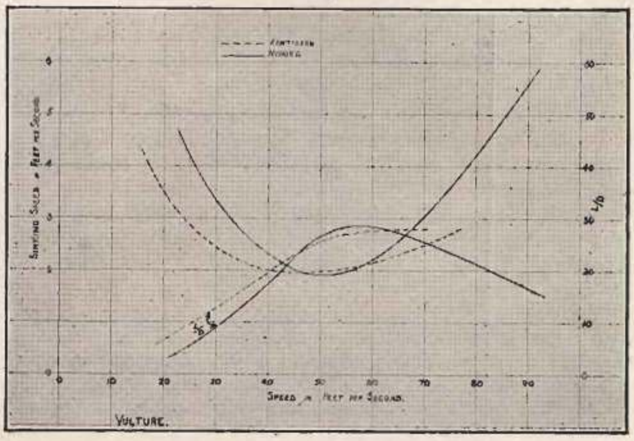
I am sorry I cannot follow "Kentigern's" calculations, as I am conversant neither with the formulæ employed nor with his methods. I see, however, how the different values of $K_1$ are obtained for the different velocities by the formula given, but I do not understand how this can be applied to this particular wing under different conditions, as the angle of incidence is apparently neglected. To my surprise the result arrived at seems to fit fairly well with my calculation, and I am not prepared to say which is the more accurate, as I have insufficient information of the actual soaring and sinking speeds of birds to afford me the necessary verification of my formulæ. I do not use the results of wind-tunnel tests, as I do not believe in them. At least, I have seen so many contradictory results that I do not think they can be relied upon as soon as the conditions are altered to any extent. On the other hand, I admit that the knowledge of the whole problem of soaring is so vague that one must be very careful in predicting anything for conditions out of the beaten track, and that those who know least of the subject are the first to condemn anything new without being able to give any reason.

In calculating the performance of the vulture from Mr. Vine's dimensions for the span, weight and wing area, I am unable to allow for the slotted wing, as I have never had any information on this subject. I believe, however, that it is only when flying slowly that the bird uses its power to slot its wing tips.

It is a well-known fact that if two square kites of similar overall dimensions are flown in the same wind velocity, the one having a piece cut out of the middle equal to half its area, while the other is whole, the pull in the string will be the same in each case.

This may account for the small wing area given, but I am prepared to say how much the effective area is increased by the slotting, and we shall consider it in discussing the curves as calculated by "Kentigern" and those of my own calculation.

The thickness of the wing arm and the wing curvature has also not been given, and I have calculated the thickness of the wing at the shoulder and assumed the curvature of the top or suction side of the wing is as it should be while the underside is assumed to be flat as it probably will be at the higher speeds. At the lower speeds there may be some camber, and the flying speed should therefore be somewhat slower than my calculations show.




I give herewith a performance calculation and curves of sinking speed and gliding angle for the vulture and for the TERN sailplane. These calculations have been made in accordance with my own theories, and I would point out that not a single "variable" constant (if I may use the expression) has been used. This means that anyone who can use a slide-rule may calculate the performance of any bird or glider using nothing more than the formulæ here employed and the dimensions of the glider, provided that it is of reasonably good aerodynamic design. Naturally, a formula cannot allow for any unnecessary resistance-producing fitting, and this must be found by test.

Comparing the skin friction resistance with the dynamical resistance of the body in the two calculations, we find that the dynamical is about three times the frictional resistance for the vulture's body, while for the TERN sailplane the body frictional resistance is nine times the body dynamical resistance.

It is obvious therefore that, while the dynamical resistance of the TERN body may be neglected, the dynamical resistance of the vulture's body must be taken into account. In the case of the sailplane, I have assumed the streamlining to be only two dimensional, and I would be very grateful if anyone could give me definite information of the actual performance, as my calculation is based on details given in *Flight*, and some of the dimensions were scaled off a small scale drawing.

As all my calculation is in the metric system, I have converted the sinking speed, or work per unit of weight per second, into feet for the vulture. Assuming a man weighing 168 lb. can, for a short time, work at the rate of 1 h.p. or 550 ft./lb. per second, we find that the vulture should do $\frac{550}{168} \times \sqrt[3]{\frac{168}{18 \cdot 6}} = 6.8$ foot/lb. per second per lb. weight. I am unable to say for what period the vulture could maintain this rate of work, but probably it would be only able to do so for a short time and it is unlikely

## VULTURE.

$W = 8{\cdot}3$ kg. $\quad S = 2{\cdot}55$ m. $\quad A = 0{\cdot}856$ m². $\quad T = 0{,}035$ m. $\quad B_D = 0{\cdot}227$ m. $\quad B_L = 0{\cdot}7$ m.

$\sqrt[6]{W} = 1{\cdot}42. \quad k_d = 1{\cdot}13. \quad k_a = 3{\cdot}36.$

$b = \frac{A}{S} = 0{\cdot}335. \quad b_0 = 0{,}335(1 - e^{-4b}) = 0{\cdot}245. \quad n = 7{\cdot}6.$

$f_1 = 1{\cdot}84 \times 2 \times A \times 10^{-4} = 0{\cdot}0302 \times 10^{-2}.$

$f_2 = 1{\cdot}84 \times 0{\cdot}5 \times 10^{-4} = 0{\cdot}0092 = 10^{-2}.$

$f_3 = \pi/4 \times \frac{1{\cdot}3}{10} \times B_D^2\left(\frac{B_D}{B_L}\right)^{2{\cdot}5} = \frac{0{\cdot}0316 \times 10^{-2}}{0{\cdot}071 \times 10^{-2}}$

Total $= 0{,}071 \times 10^{-2}$.

$\tan \alpha_1 = \frac{0{\cdot}035}{2 \times 0{\cdot}335} = 0{\cdot}052$ or $\alpha = 3°$.

$W/S = 3{\cdot}25$ kg./m. $\quad W/A = 9{\cdot}7$ kg./m².

$fw = \frac{2 \times 1{\cdot}3}{10} \times {\cdot}856 \tan^3 (\alpha_1 + \alpha_2) = {\cdot}22 \tan^3 (\alpha_1 + \alpha_2)$

Surface of Body Head and Tail = 0·5 m².

$C = \sqrt[3]{\frac{k_s}{K_s + K_A}} \quad V = C\sqrt[6]{W}.$

| $\alpha_1$ | $\alpha_2$ | $K_s \times 10^{-3}$. | $K_a \times 10^{-3}$. | $(K_s+K_a)10^{-3}$ | $C$ | $V$ | $fw$ | $\Sigma f$ | $\Sigma f V^2$ | $W \sin \alpha_2$. | $R$ | m.kg./sec. | m.kg./m/sec. | $L/D$ | $\beta = \frac{10}{1.3}\frac{W/A}{V^2}$ | Sinking Speed, ft./sec. | $V$ ft./sec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2½ | −½ | 0·27 | −0·125 | 0·145 | 19·8 | 28·2 | 0·003 | 0·074 | 0·59 | −0·07 | 0·52 | 14·7 | 1·77 | 15·9 | 0·094 | 5·8 | 91·5 |
| 3 | 0 | 0·384 | 0 | 0·384 | 14·3 | 30·3 | 0·004 | 0·075 | 0·31 | 0 | 0·31 | 6·3 | 0·76 | 26·8 | 0·18 | 2·5 | 66 |
| 3½ | ½ | 0·52 | 0·125 | 0·645 | 12 | 17·1 | 0·005 | 0·076 | 0·22 | 0·07 | 0·29 | 5 | 0·6 | 28·5 | 0·255 | 1·96 | 55·7 |
| 4 | 1 | 0·67 | 0·25 | 0·92 | 10·7 | 15·2 | 0·007 | 0·078 | 0·18 | 0·14 | 0·32 | 4·9 | 0·59 | 26 | 0·325 | 1·93 | 49 |
| 4½ | 1½ | 0·84 | 1·375 | 1·22 | 9·75 | 13·8 | 0·011 | 0·082 | 0·155 | 0·28 | 0·37 | 5·1 | 0·61 | 22·4 | 0·395 | 2·0 | 45 |
| 5 | 2 | 1·04 | 0·50 | 1·54 | 9 | 12·8 | 0·015 | 0·087 | 0·144 | 0·29 | 0·44 | 5·6 | 0·68 | 18·8 | 0·46 | 2·23 | 41·7 |
| 6 | 3 | 1·46 | 0·75 | 2·21 | 8 | 11·4 | 0·025 | 0·096 | 0·126 | 0·435 | 0·56 | 6·4 | 0·77 | 14·8 | 0·58 | 2·5 | 37 |
| 7 | 4 | 1·93 | 1·0 | 2·93 | 7·3 | 10·4 | 0·041 | 0·112 | 0·122 | 0·58 | 0·70 | 7·3 | 0·88 | 11·8 | 0·7 | 2·9 | 33·8 |
| 8 | 5 | 2·5 | 1·25 | 3·75 | 6·7 | 9·6 | 0·060 | 1·131 | 0·121 | 0·72 | 0·84 | 8·1 | 0·98 | 9·9 | 0·81 | 3·2 | 31 |
| 10 | 7 | 3·76 | 1·65 | 5·41 | 5·9 | 8·4 | 0·12 | 0·191 | 0·135 | 1·01 | 1·15 | 9·7 | 1·17 | 7·2 | 1·06 | 3·85 | 27·2 |
| 12 | 9 | 5·2 | 2·05 | 7·25 | 5·4 | 7·65 | 0·21 | 0·281 | 0·165 | 1·3 | 1·5 | 10·5 | 1·27 | 6·5 | 1·28 | 4·12 | 25 |
| 15 | 12 | 7·7 | 2·7 | 10·4 | 4·75 | 6·75 | 0·42 | 0·491 | 0·225 | 1·7 | 2·9 | 19·5 | 2·35 | 3·5 | 1·68 | 7·7 | 22 |

## "TERN."

$W = 185$ kg. $\quad S = 15{\cdot}25$ m. $\quad A = 19{\cdot}5$ m². $\quad T = 0{\cdot}3$ m. $\quad B_D = 0{\cdot}75$ m.. $\quad B_L = 7{\cdot}5$ m.

$\sqrt[6]{W} = 2{\cdot}4. \quad k_s = 0{\cdot}9. \quad k_a = \text{em } 0{\cdot}7.$

$b$ max. $= 1{\cdot}87. \quad \frac{A}{S} = 1{\cdot}28 = b$ mean. $\quad \therefore b(1 - e^{4b}) = 1{.}27.$

$f_1 = 1{\cdot}84.2.A \times 10^{-4} = 0{\cdot}0072.$

$\tan \alpha = \frac{0{\cdot}3}{1{\cdot}87} \times 3/4 = 0{\cdot}12$ or $\alpha = 7°$.

$f_2 = 1{\cdot}84 \times 26{\cdot}6 \times 10^{-4} = 0{\cdot}0049.$

$\frac{W}{S} = 12{\cdot}5$ kg./m. $\quad \frac{W}{A} = 9{\cdot}5$ kg./m².

$\frac{W}{S} = 12.{\cdot}5$ kg./m. $\quad \frac{W}{A} = 9{\cdot}5$ kg./m.²

$f_3 = \frac{\pi \times 1{\cdot}3}{4 \times 10} \times 0{\cdot}75^2 \left(\frac{0{\cdot}75}{7{\cdot}5}\right)^2 = 0{\cdot}00057.$

Body Elevator and Rudder Surface = 26.6 m.²

$f_w = \frac{2 \times 1{\cdot}3}{10} A \tan^3 (\alpha_1 + \alpha_2) = 5{\cdot}1 \tan (\alpha_1 - \alpha_2).$

$f_4 =$ Skid and Head $\quad \frac{= 0{\cdot}00033}{0{\cdot}01300}$

or $1{\cdot}3 \times 10^{-2}$.

$C = \sqrt[3]{\frac{k_s}{K_s + K_A}} \quad V = C\sqrt[6]{W}.$

| $\alpha_1$ | $\alpha$ | $K_s$ 10³ | $K_A$ 10³ | $K_s + K_A$ 10⁻³ | $C$ | $V$ | $f_w$ 10³ | $\Sigma f$ 10³ | $\Sigma f \times V^2$ | $W \sin \alpha$ | $R$ | m.kg./sec. | m.kg./kg. | $\gamma$ | $\beta$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | −1 | 1·46 | −1·435 | 0·025 | 33 | 79 | 0·6 | 1·9 | 11·8 | −3·25 | 114·75 | 9000 | 49 | 1·65 | — |
| 6½ | −½ | 1·7 | −0·725 | 0·975 | 9·7 | 23·2 | 0·75 | 2·05 | 11·0 | −1·62 | 9·38 | 218 | 1·18 | 19·7 | 0·135 |
| 7 | 0 | 1·93 | 0 | 1·93 | 7·75 | 18·6 | 0·94 | 2·24 | 7·7 | 0 | 7·7 | 143 | 0·78 | 24 | 0·21 |
| 7½ | ½ | 2·21 | +0·725 | 2·93 | 6·75 | 16·2 | 1·16 | 2·46 | 6·45 | 1·62 | 8·07 | 131 | 0·71 | 23 | 0·275 |
| 8 | 1 | 2·5 | +1·435 | 3·74 | 6·1 | 14·7 | 1·41 | 2·71 | 5·9 | 3·25 | 9·15 | 134 | 0·73 | 20·2 | 0·335 |
| 9 | 2 | 3·12 | 2·92 | 6·04 | 5·3 | 12·7 | 2·00 | 3·3 | 5·3 | 6·5 | 11·8 | 150 | 0·810 | 15·7 | 0·45 |
| 11 | 4 | 4·5 | 5·75 | 10·2 | 4·45 | 10·7 | 3·75 | 5·05 | 5·8 | 13 | 18·8 | 202 | 1·1 | 10 | 0·63 |
| 15 | 8 | 7·73 | 10·7 | 18·4 | 3·65 | 8·8 | 9·8 | 11·1 | 8·6 | 26 | 34·6 | 305 | 1·65 | 5·35 | 0·93 |
| 21 | 14 | 13·4 | 16·6 | 30 | 3·12 | 7·5 | 28·5 | 29·8 | 16·8 | 45 | 61·8 | 465 | 2·5 | 3 | 1·3 |

that it could keep up more than one-third of this output, or, say, 2 ft./lb. per second per lb. for any length of time.

As a man can only maintain a continuous working rate of .5 ft./lb. per second per lb., it will be appreciated that this does not underestimate the vulture's working capabilities.

From the table it will be seen that for the minimum work of 2 ft./lb. per second per lb., the vulture's cruising speed will be about 33-3-5 m.p.h. when flying under its own power.

Comparing the two calculations, "Kentigern's" and my own, we find that my method gives a higher minimum and a lower maximum speed.

It may be that the more orthodox method is the more accurate at the lower speeds, as I have not allowed for any slotting effect, and for reasons of ease of working I have not considered the second power term of the lift coefficient.

In view of the work required, my method would appear to be the more accurate at the higher speeds, since, as previously mentioned, the maximum speed of the vulture when exerted to its limit is in the neighbourhood of 50 m.p.h., which means a working rate of $3\frac{1}{2}$ ft./lb. per second per lb.

Curiously enough, the two calculations coincide in the value of the maximum L/D.

It seems curious that the optimum gliding angle given by the orthodox method should correspond to the maximum speed of which the bird is capable, and I should like to know more of the method by which this result is obtained.



# NEWS FROM THE CLUBS

**BRADFORD AND COUNTY GLIDING CLUB.**

Saturday, June 11th, and Sunday, June 12th.

On the Saturday a light east wind was coming up the Reservoir slope, and flights of up to 40 sec., with turns, were carried out on this slope till dusk. REYNARD was used, as DICKSON is having a new wing built as a result of our Whitsuntide crash. On Sunday, the wind was very variable, but of such strength that its direction had always to be taken into account, with the result that during the day five different slopes were used to meet the varying wind direction. Some very good flying was done between the intervals of rushing the machine from one spot to another, and good progress was made. We have a good slope for every wind direction except south, and Sunday was the sort of day that taught us really to appreciate our site.

Saturday, June 18th, and Sunday, June 19th.

Flying was suspended for this week-end owing to the visit of Sir Alan Cobham for National Aviation Day. The Club was well represented at Yeadon, where it had a machine and an inquiry tent on view in a roped-off enclosure. Great interest was shown, much propaganda was distributed, and new members were enrolled. Mr. Jones, our Hon. Secretary and Chief Instructor, gave a masterly exhortation through the public address unit, which was placed at our disposal for a short time by courtesy of Sir Alan. In spite of our activity in connection with National Aviation Day, repair work on DICKSON and alterations to REYNARD were carried on throughout the week-end.

**Air view of the London Gliding Club Hangars and Club-house, taken by F. B. Thomas while soaring in a "Prüfling."**