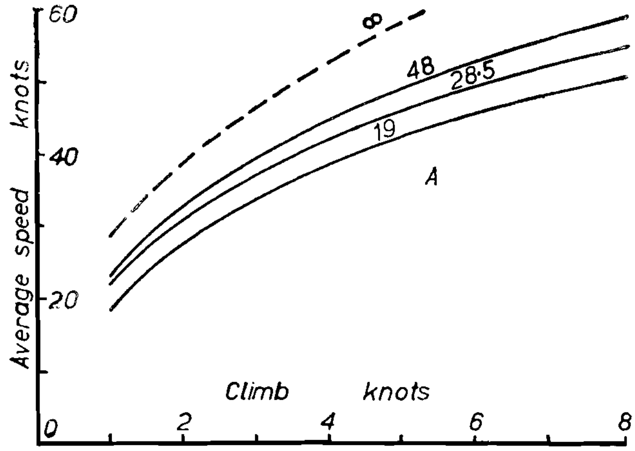

Fig 6 Average cross-country speed as a function of achieved rate of climb for the gliders in Fig 5

Now we wish to fly fast between thermals, for which we want a small chord and a corresponding high wing-loading. Let us assume that, by retracting a suitable flap, we can decrease the chord to two-thirds of its circling-flight value (i.e., we extend a 50 per cent chord flap for circling). Even with our fairly modest "circling" glider, we now get A = 28.5 and a wing-loading of 6.35 lb/sq ft.

The effect is shown in Fig. 5. The high-speed performance is distinctly improved, compared with the A = 19 case. If we now consider a fairly outrageous glider, circling at $C_L = 1.8$ with A = 32, and we assume an equivalent change in geometry, the aspect ratio in cruising flight becomes 48, and we are operating on an even better curve.

Fig. 6 shows cruising speed plotted against rate of climb. Since all these gliders have roughly the same minimum rate of sink (1.2 knots) the curves are directly comparable. The worst curve represents roughly the present state of the art, whilst the other two show improvements of about 10 and 17 per cent respectively.

To pursue variable geometry *ad absurdum*, it is worth seeing what happens if we suppose that, whilst maintaining our climb configuration, we can shrink the chord indefinitely. We are still left with the fuselage drag and the wing induced drag, but we can plot the performance curve shown by the dotted line in Fig. 5. This leads to a 40 per cent improvement in cross-country speed over our conventional glider, as shown in Fig. 6. If the efficiency of the latter (as

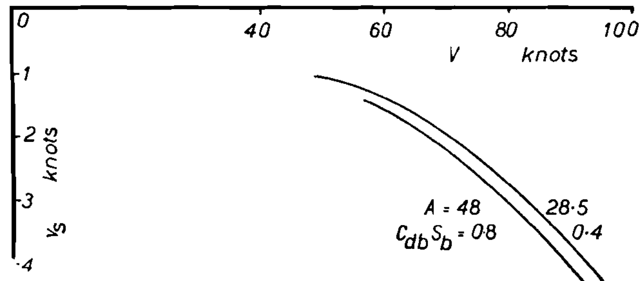

Fig 7 Effect of halving profile drag of parts of the glider other than the wing. C_{db} is the drag coefficient based on the fuselage cross-section S_b square feet

originally defined) is about 35 per cent, it looks as if the best we can do is around 50 per cent.

But once one starts to achieve very high aspect ratios, the drag of the parts other than the wing becomes very important. All the previous diagrams assume $C_{db}S_b$ equals approximately 0.8 sq. ft. (which includes drag of tail, etc). This is about 50 per cent higher than that of a body of revolution of the cross-sectional area of the Dart (4.5 sq. ft), plus tail, and is probably quite realistic. But if we were content to go to even smaller cross sections, and generally clean up the fuselage, we might be able to halve this figure.

The effects of doing so are rather gratifying: with A = 28.5 and half the fuselage drag previously assumed, we are now better than the A = 48 machine previously considerd (Fig. 7) and the cross-country speed is up by 22 per cent. In fact, we would be slightly better off than this figure indicates, since the minimum rate of sink would also be improved.

So the reduction of the drag of parts other than the wing seems to be a very profitable line to pursue. This is to be expected, since the profile drag predominates at high speeds. Also, it seems much more straightforward than trying to achieve quite outrageous aspect ratios in cruising flight.

To summarize, it looks as if one might expect an improvement of the order of 20 per cent over present performances by taking steps to reduce the fuselage drag, and by having an aspect ratio which has about its present value in circling flight and about one and a half times this value in cruising filght. None of this (apart from getting down the fuselage drag) involves any extraordinary aerodynamics or structures, but it does involve a great deal of mechanical ingenuity.

Historical Notes

There is little information on how Penaud (1850-1880) carried out his investigations, or what mental and observational processes enabled him to reach the conclusions he did. What is astonishing is that he discovered so much, as can be seen by the diagrams that he left.

Penaud realised that since the wind could not penetrate obstructions, it must either go round or over them, and following from this he deduced that if the obstruction was a ridge, the wind would blow up and over the top. This was confirmed by his observations of birds which soared, without flapping, so long as they stayed in the region of rising air on the windward sides of cliffs and hills.

The understanding of slope lift is not difficult, but Penaud also realised that under some conditions atmospheric waves were set up to the lee of hills, in which birds could soar. He was not able to work out properly what happened, and his diagrams are not accurate by today's knowledge, but it is remarkable that he realised at all that waves could exist in the atmosphere.

His most interesting work was on thermals. He deduced that the vertical up-currents in which birds soared were caused by convection, and he produced diagrammatically his ideas of the structure of thermals, which he believed to circulate in the form of a vortex ring, or "doughnut." This theory, which is now generally accepted, was not propounded again until the 1950s. His writings contain clearer observations on thermal activity than are made by many pilots today, even with the knowledge which now exists.

– The Story of Gliding