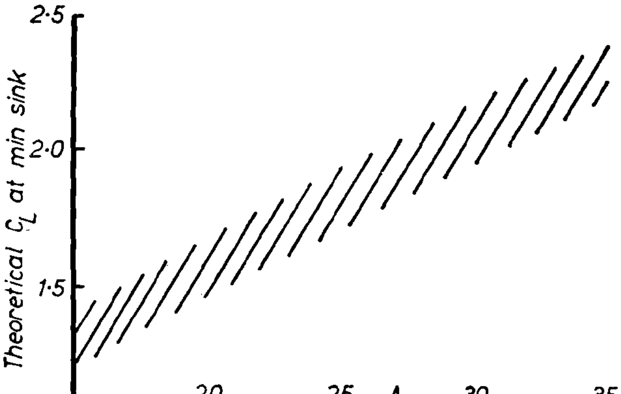


Fig 3 Theoretical lift coefficients at minimum sink as a function of aspect ratio. The shaded region indicates values for modern gliders

our efficiency of design by comparing actual cross-country speeds with the above ideal. The figures suggested by this expression are fairly startling: given three-knot rates of climb (a fair UK day) and $(L/D)_{max}$ of 40, the average speed would be 120 knots. The imagination boggles at the thought of Texas. On this basis, the efficiency of a current good glider of fixed geometry with a rate of climb of three knots is about 35 per cent. So there is plenty of room for improvement.

Having decided that we want variable-geometry sailplanes, it now becomes possible to achieve something nearer the optimum by designing for climbing and cruising separately, instead of compromising between the two. Let us first consider the requirement for climbing in thermals.

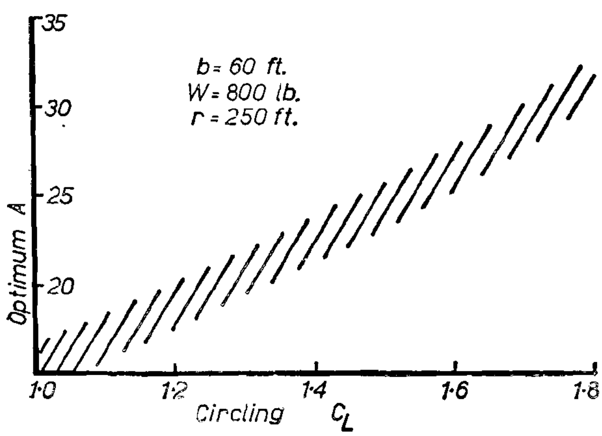
Calculations on gliders are often made on the assumption that the rate of sink is given by

$$V_s = AV^3 + B/V.$$

This is reasonably true at fairly high speeds, but for clean machines with aspect ratios of the order of 20 it cannot apply near the minimum-sink condition, because this condition requires excessively high lift coefficients.

Choosing a reasonable profile-drag for the wing, and assuming constant fuselage size, the theoretical values for the lift coefficient at the minimum rate of sink speed are shown in Fig. 3.

Now it seems unlikely that, for the higher aspect ratios, we are going to attain such high lift coefficients. To some extent we can by using flaps. But flaps tend to increase the profile drag and the final benefit may not be very noticeable.



At all events, it is clear that gliders would, ideally, be operated at quite high lift coefficients in circling flights. Such considerations have led to the development (notably by Eppler and Wortmann) of airfoil sections having low drag at high lift coefficients and a high maximum lift coefficient.

Wortmann's airfoils show about 18 per cent less drag than the NACA airfoils of about the same thickness, have low-drag buckets extending to higher lift coefficients and have better maximum lift coefficients. Such airfoils are now used on various modern gliders, with very satisfactory results.

With such an airfoil, the end of the low-drag buckct corresponds to about $C_{dp}=0.009$ at $C_L=1.1$ or 1.2. The use of small camber-changing flaps produces some improvement, but at higher lift coefficients the drag rise is quite rapid, and one would not really like to operate in these regions. There is a limit to the lift coefficient at which airfoils will operate at a reasonably low drag coefficient, defined by the properties of boundary-layers.

At all events, it seems useful to perform the converse calculation: to choose a working lift coefficient in thermals, to choose a radius of turn, and then to decide on the optimum aspect ratio to give minimum rate of sink under these conditions assuming a given weight. The nature of the compromise is obvious: at high aspect ratios the forward speed at the given lift coefficient increases and hence, for a given radius of turn, the angle of bank increases. This increases the induced drag. At low aspect ratios, the large wing area leads to an increase in profile drag.

It will be seen from Fig. 4 that the result is much as one would expect. For values of lift coefficient appropriate to NACA 6-series wings, quite a modest aspect ratio is best, and if one wanted a club glider which earned money by staying up, the aspect ratio would be about 16.

For all combinations of lift coefficient and aspect ratio, the forward speed and rate of sink are much the same, with a slight bias in favor of the more extreme design. But one would lose relatively very little by playing safe and going to $C_L = 1.2$, aspect ratio $A=19$. We now have rather a good glider for flying quite slowly (about 33 knots) in circling flight.

Fig. 4 is not to be taken too literally, since it really requires an optimization calculation based on an assumed variation of thermal strength with radius. As it stands, it is merely based on assuming a typical radius of turn.

Fig 4 (left) Aspect ratio for minimum sink rate in circling flight as a function of lift coefficient. Fig 5 (below) The performance curves for gliders of various aspect ratios. All gliders are assumed to have a span of 60 ft., a gross weight of 800 lbs. and a turn radious of 250 ft. (Dot indicates operating point in thermals.)