Glider performance: A new approach

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The measured performance of gliders is normally stated by means of a curve showing sinking speed against forward speed. Those who wish to determine cross country performance then use the construction shown in fig. 1 which gives them a curve of achieved cross country speed against achieved rate of climb. Comparisons are then frequently made between different gliders on the basis of the speeds achieved at a rate of climb obtained for each glider by subtracting its minimum sinking speed (or perhaps better 1.5 times min. sink) from an assumed absolute thermal strength.

Unfortunately such comparisons are not valid since they make no allowance for the differing speeds at which the gliders achieve their minimum sink. The effect of varying speed is to change the circling radius and it is therefore necessary to make allowance not only for the sinking speed of the glider in a turn but also for the decreasing strength of a thermal with radius. In other words, performance comparisons can only be made valid by basing them on a standard thermal.

As is well known, thermals come in many shapes and sizes; what is representative of the thermals in one particular country will certainly err greatly in other areas. Even in any particular area thermals will vary significantly from day to day and with height. What follows is therefore aimed at defining average English conditions at average English heights; the *method* is however applicable in any other case.

Circling performance

Given the straight flight minimum sink performance of a particular glider, it is relatively easy to draw a curve showing the performance of this glider when flown in circling flight at various angles of bank but with the same angle of attack.

For those interested the formulae are:

$$U_T = \frac{U_L}{(\cos \varnothing)^{\frac{3}{2}}} \cdot R = \frac{0{,}089\, V_L^2}{\sin \varnothing}$$

where

U_T = sinking speed in the turn (knots)
$\varnothing$ = angle of bank
R = radius of turn (ft.)
U_L = min. sink speed in straight flight (knots)
V_L = speed for min. sink in straight flight (knots)

Theoretically, a slightly lower sinking speed can be achieved at any particular radius by flying at slightly higher angle of attack, but it is reasonable to offset this small gain against the inevitable inefficiencies of circling flight. It is therefore possible that the sink rates obtained from the formulae may tend to be lower rather than higher than those an average pilot can expect to achieve. However, for the purpose of this paper, it will be assumed that this performance can be achieved.

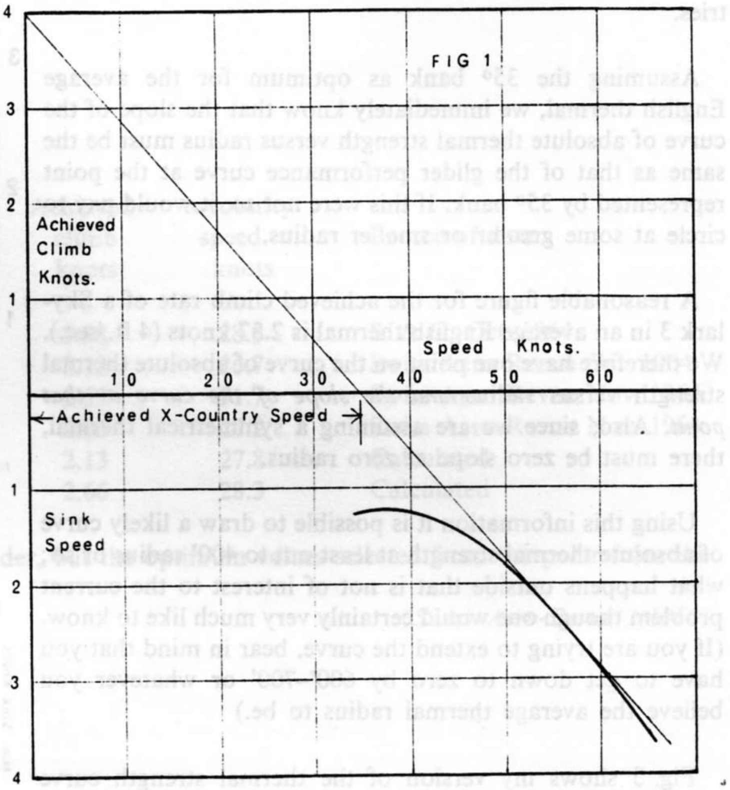

Fig. 1

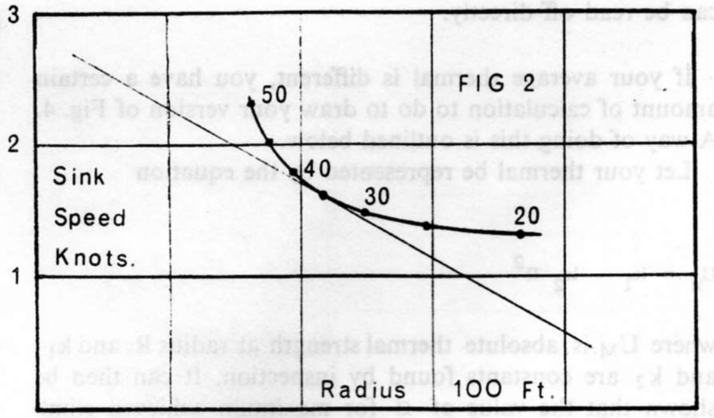

Fig. 2

Fig. 2 shows the circling performance curve for a Skylark 3 based on the measured min. sink performance (1.2 knots at 37.5 knots) given in "Sailplane and Gliding", Oct. 1964. Marked along the curve are spot values of the angle of bank.

Experience of flying a Skylark 3 leads me to believe that best results in an average English thermal are achieved when the angle of bank is about 35°. There will be many who will not agree with this value and to them I can only offer the method of these calculations, not the results; similarly, there may be others in other countries who may wish to try to produce results for the typical thermals of their own countries.

Assuming the 35° bank as optimum for the average English thermal, we immediately know that the slope of the curve of absolute thermal strength versus radius must be the same as that of the glider performance curve at the point represented by 35° bank. If this were not so, it would pay to circle at some greater or smaller radius.

A reasonable figure for the achieved climb rate of a Skylark 3 in an average English thermal is 2.37 knots (4 ft./sec.). We therefore have one point on the curve of absolute thermal strength versus radius *and the slope of the curve at that point*. Also, since we are assuming a symmetrical thermal, there must be zero slope at zero radius.

Using this information it is possible to draw a likely curve of absolute thermal strength at least out to 400' radius or so; what happens outside that is not of interest to the current problem though one would certainly very much like to know. (If you are trying to extend the curve, bear in mind that you have to get down to zero by 600'–700' or whatever you believe the average thermal radius to be.)

Fig. 3 shows my version of the thermal strength curve based on the information derived above.

Using this curve it is now possible to determine the achieved climb capability of any particular glider given only its min. sinking speed and speed for min. sink. This calculation has been done for a series of combinations of min. sink and speed for min. sink and has yielded the curves shown in Fig. 4. From these curves (isoclimbs) the achieved climbing rate of any particular glider in my average English thermal can be read off directly.

If your average thermal is different, you have a certain amount of calculation to do to draw your version of Fig. 4. A way of doing this is outlined below.

Let your thermal be represented by the equation

$$U_M = k_1 - k_2 R^2$$

where U_M is absolute thermal strength at radius R, and k_1, and k_2 are constants found by inspection. It can then be shown that the value of ∅ for maximum achieved climb (U_A) for any particular combination of V_L and U_L is given by

$$\tan^4 \varnothing \cos^{1/2} \varnothing = \frac{0{,}0106\ k_2 V_L^4}{U_L}$$

which is easily solved by drawing a curve of

$$\tan^4 \varnothing \cos^{1/2} \varnothing$$

against ∅.

Using the value of ∅ obtained U_A can now be obtained from

$$U_A = k_1 - \frac{0{,}0079\ k_2 V_L^4}{\sin^2 \varnothing} - \frac{U_L}{\cos \frac{3}{2} \varnothing}$$

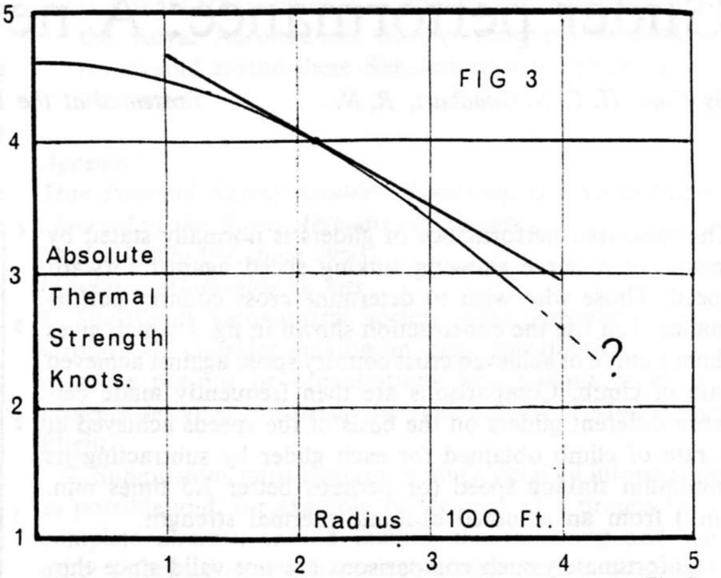

Fig. 3

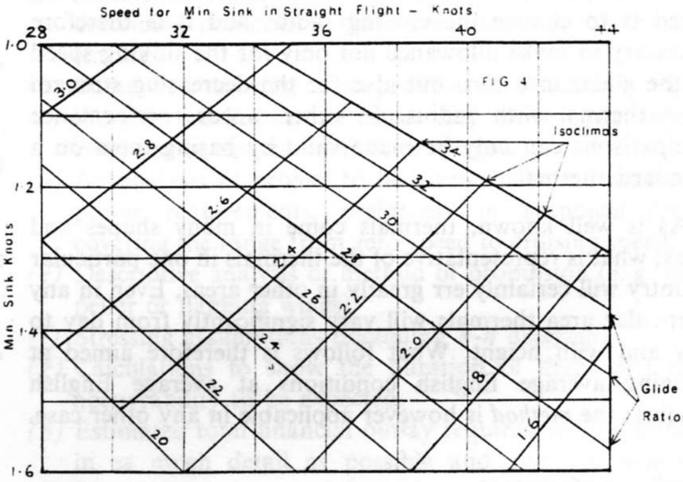

Fig. 4

Reverting now to Fig. 1, instead of drawing the tangent from an arbitrarily selected rate of climb, it can be drawn from the rate of climb read off from Fig. 4 for that particular glider. It is thus immediately possible to read off the achieved cross-country speed of that particular glider when flown in conditions represented by my average English thermal.

This has been done for a number of gliders for which satisfactory performance information exists and the results are shown in Table 1. The last two lines in the table have been included to indicate the effect of weight changes on performance. The calculated performance at different weights for a Skylark 3 is based on the assumption that C_D and C_L maintain their values at any particular angle of attack. i. e.

changes due to change of Reynolds Number are ignored. If my average thermal is correct, it would appear that a Skylark 3 should be flown lighter for best performance on average English days.

Another significant conclusion that can be drawn from Fig. 4 is the measure of increased sink rate that can be tolerated for a given increase in lift when considering the merits of flap installations. It would appear that any device which will lower circling speed by x % while incurring a sink penalty of less than about 1.5 x % will be advantageous.

But perhaps the most important conclusion of all is that "hot ships" and average English thermals are not compatible. The right wing loading would appear to be of the order of 4–4½ lbs/sq. ft.

Table 1

Glider	wt. lb.	Min. sink knots	Speed knots	Achieved climb knots	x-country speed knots	Source of data
Skylark 3F	752	1.2	37.5	2.38	28.3	S. & G. Oct. 1964
Ka 6-CR	673	1.4	37.5	2.13	26.7	Swiss Aero Revue Oct. 1964
Phönix T	580	1.42*	28.7*	2.59	31.7	Swiss Aero Revue Nov. 1964
Jaskolka	792	1.51	36.2	2.06	27.2	Swiss Aero Revue Nov. 1964
Skylark 3F	852	1.27	39.9	2.13	27.8	Calculated
Skylark 3F	652	1.11	34.9	2.66	28.3	Calculated

* These figures are not actually the true min. sink of this glider, but the optimum values selected from the polar from the point of view of circling in a thermal.

(Swiss Aero-Revue 1/1966)