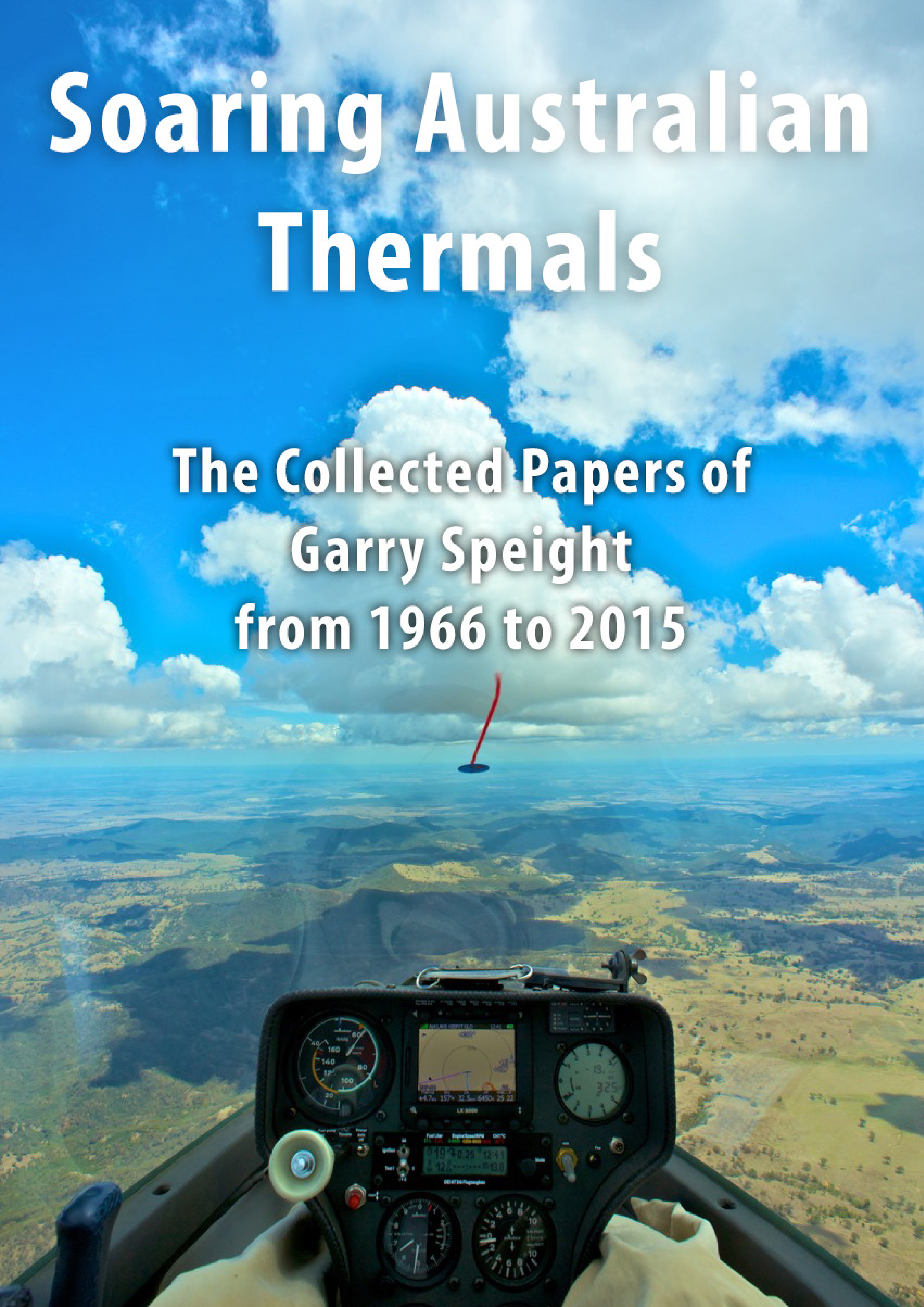
Soaring Australian Thermals

The Collected Papers of Garry Speight from 1966 to 2015



The Thermal Interception Diagram

By Garry Speight

This is the first of a series of articles about how a glider's wing loading, which can be changed using water ballast, affects its performance. In this article I try a new way to make it clear how the glide speed to a thermal, and the rate of climb in the thermal affects the average speed.

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It is theoretically correct, and proved by experience, that, when flying cross-country using thermals, you get a greater average speed by flying faster than the speed for best glide angle, and by flying faster between strong thermals than between weak ones.

It is possible to calculate the best inter-thermal speed for each thermal strength from the performance polar curve for any glider. This calculation has been incorporated in the MacCready Ring, and subsequently in various Optimum Speed To Fly instruments or Flight Directors.

The mathematical justification for basing gliding speed on thermal strength is no doubt sound, but I have some difficulty understanding it myself and it is possible that others have the same trouble.

The standard graphical demonstration is given by Frank Irving in New Soaring Pilot (Welch, Welch and Irving, 1968, p. 44-48). It involves drawing the performance polar curve of the glider (ensuring that the vertical line for zero airspeed appears on the diagram) and extending the vertical scale, which represents rates of sink, upwards to indicate rates of climb.

On the zero airspeed line a point is inserted to show a certain rate of thermal lift and from this point a tangent is drawn to the polar. The point where it touches the polar then shows the best speed to fly for that thermal strength.

To accept this demonstration requires acceptance of the argument that sink being experienced at a given time may be **added to** lift expected at some future time. I believe that a more immediately acceptable demonstration of the influence of thermal strength on best speed to fly can be made using a thermal interception diagram as described below.

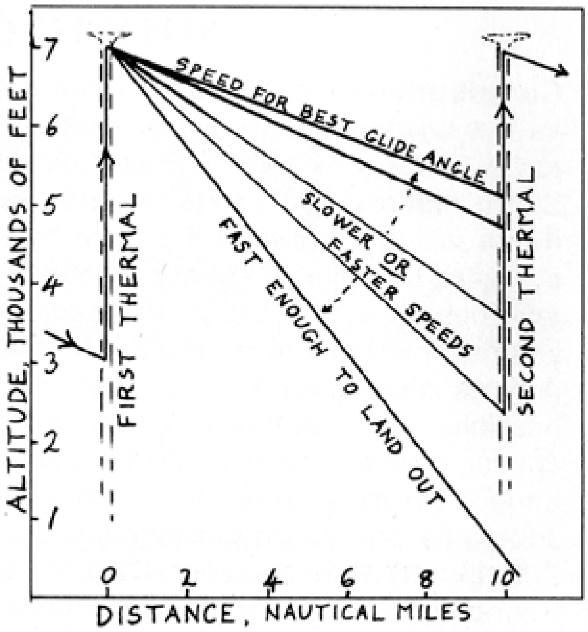

Fig 1. Altitude/Distance diagram for thermal cross-country soaring

First, consider a side view of part of a cross-country flight (Fig. 1) in which there are two thermals ten nautical miles apart, extending to 7000 ft. above the ground and not usable from ground level to about 1000 ft. All these numbers are chosen for convenience, and are not important.

A glider pilot climbs in the first thermal up to 7000 ft. and heads off for the second thermal. If he flies at the speed for best glide angle he will arrive as high as possible on the second thermal.

The angle of the uppermost flight line on Fig. 1 represents the glide angle and it clearly is the "best" glide angle. (I will not discuss lift and sink encountered between the thermals. In such conditions the best attainable glide angle will vary from one moment to the next and it will be necessary to fly at different speeds to attain a best angle depending on the lift or sink).

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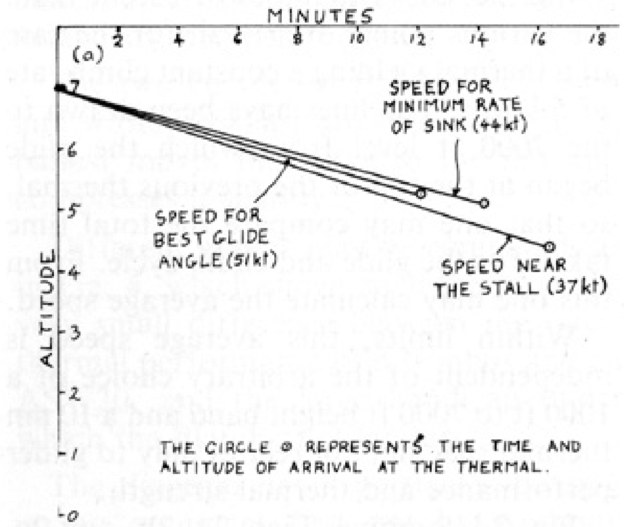

Fig 2a.

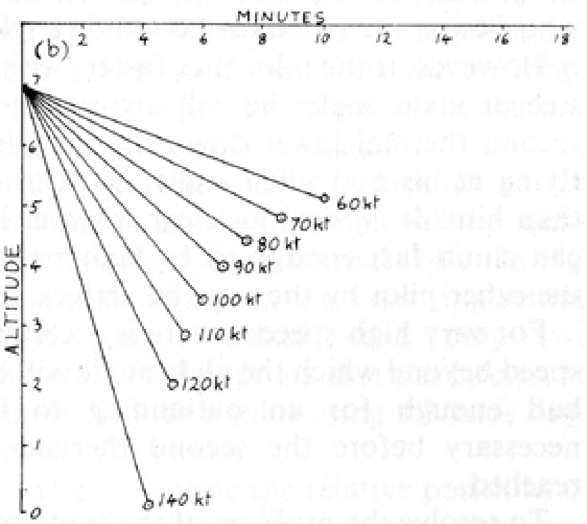

Fig 2b.

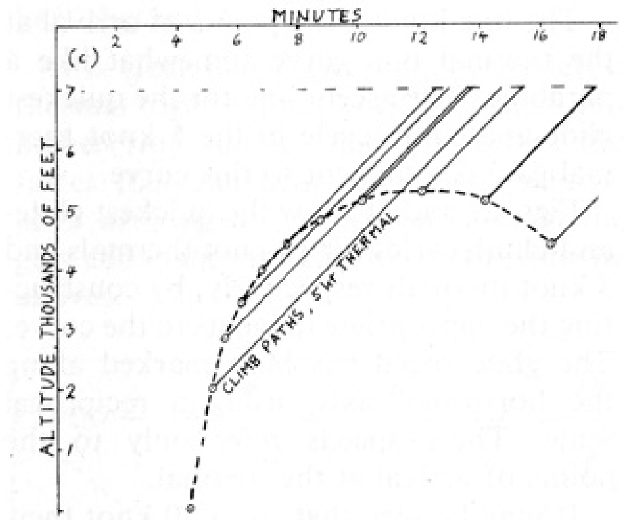

Fig 2c.

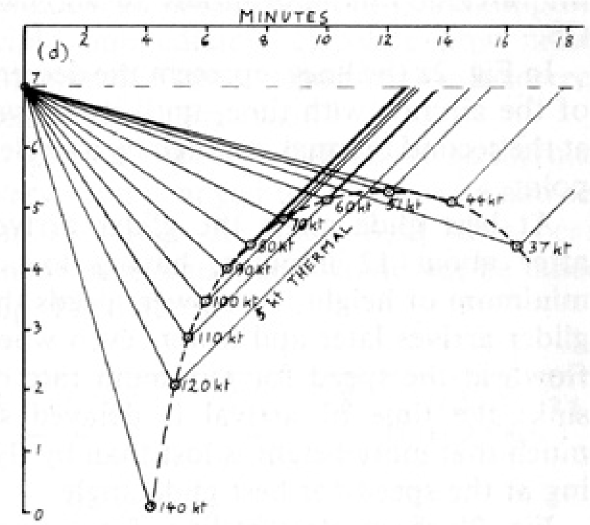

Fig 2d.

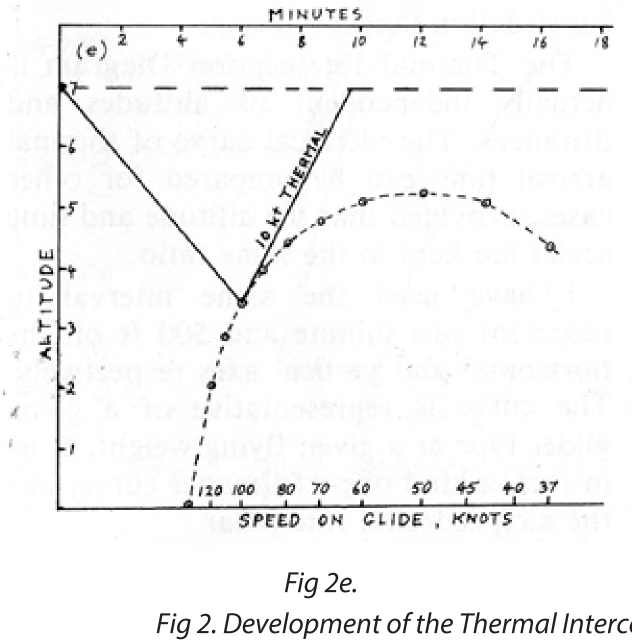

Fig 2e.

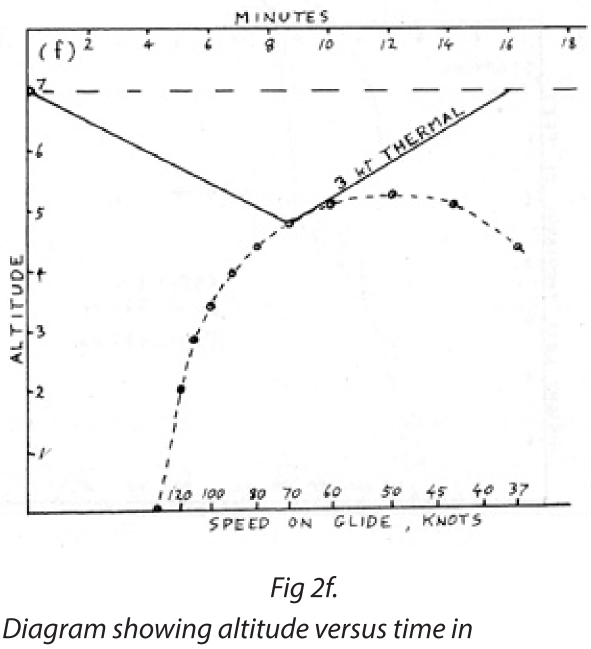

Fig 2f.

Fig 2. Development of the Thermal Interception Diagram showing altitude versus time in cross-country flight

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If the pilot flies slower, his glide angle will be steeper, he will arrive at the second thermal both lower down and later, and he cannot possibly catch up with a pilot who flew at the speed for best glide angle.

However, if the pilot flies faster, with a steeper glide angle, he will arrive at the second thermal lower down than a pilot flying at his best glide angle, but earlier than him. It is then not clear whether he can climb fast enough to be higher than the other pilot by the time he arrives.

For very high speeds, there is a certain speed beyond which the glide angle will be bad enough for an outlanding to be necessary before the second thermal is reached.

To resolve the problem of the trade-off between early arrival at the thermal and the time required to regain extra loss of height, we can construct an altitude-time diagram, somewhat like a barograph chart (Fig. 2). For convenience, I have used the same thermals as in Fig. 1 and the rates of sink appropriate to an Astir CS.

In Fig. 2a the lines represent the descent of the aircraft with time, until its arrival at the second thermal, marked by a circled point.

At best glide angle the glider arrives after about 12 minutes, having lost a minimum of height. At slower speeds the glider arrives later and lower, even when flown at the speed for minimum rate of sink: the time of arrival is delayed so much that more height is lost than by flying at the speed for best glide angle.

Fig. 2b shows descent lines for various higher speeds, with points marking the arrival times. At 140 kt. the arrival point is so low that a landing would be inevitable.

Fig. 2c shows the lines of ascent from the various points of arrival, for the case of a thermal yielding a constant climb rate of 5 knots. The lines have been drawn to the 7000 ft level from which the glide began at the top of the previous thermal, so that one may compare the total time taken for the glide and climb cycle. From this one may calculate the average speed.

Within limits, this average speed is independent of the arbitrary choice of a 1000 ft. to 7000 ft. height band and a 10 nm thermal spacing, but relates only to glider performance and thermal strength.

Fig. 2d combines Figs. 2a, 2b, and 2c, making up the complete thermal interception diagram. It is clear that a pilot flying at 85 kt. to a 5 kt. thermal will achieve the quickest cycle back to 7000 ft. altitude, and thus achieve the fastest speed. 85 knots is the MacCready speed for 5 kt. thermals in the Astir CS.

The line joining the points of arrival at the thermal is a curve somewhat like a parabola. The ascent line for the quickest glide-and-climb cycle in the 5 knot thermal case is a tangent to this curve.

Figs. 2e and 2f show the quickest glide-and-climb cycles for 10 knot thermals and 3 knot thermals respectively, by constructing the appropriate tangents to the curve. The glide speed has been marked along the horizontal axis, using a reciprocal scale. These speeds refer only to the points of arrival at the thermal.

It may be seen that for a 10 knot thermal the best glide speed is 100 knots and for the 3 knot thermal it is 70 knots, confirming that the best glide speed varies with thermal strength, and agreeing exactly with the speeds that result from the construction used by Irving.

The Thermal Interception Diagram is actually independent of altitudes and distances. The identical curve of thermal arrival time can be prepared for other cases, provided that the altitude and time scales are kept in the same ratio.

I have used the same interval to represent one minute and 500 ft. on the horizontal and vertical axes respectively. The curve is representative of a given glider type at a given flying weight. It is, in fact, a kind of performance curve, like the airspeed/sink rate polar.

The thermal interception diagram has a number of uses. In a separate paper I will use it to demonstrate the effect of water ballast on cross-

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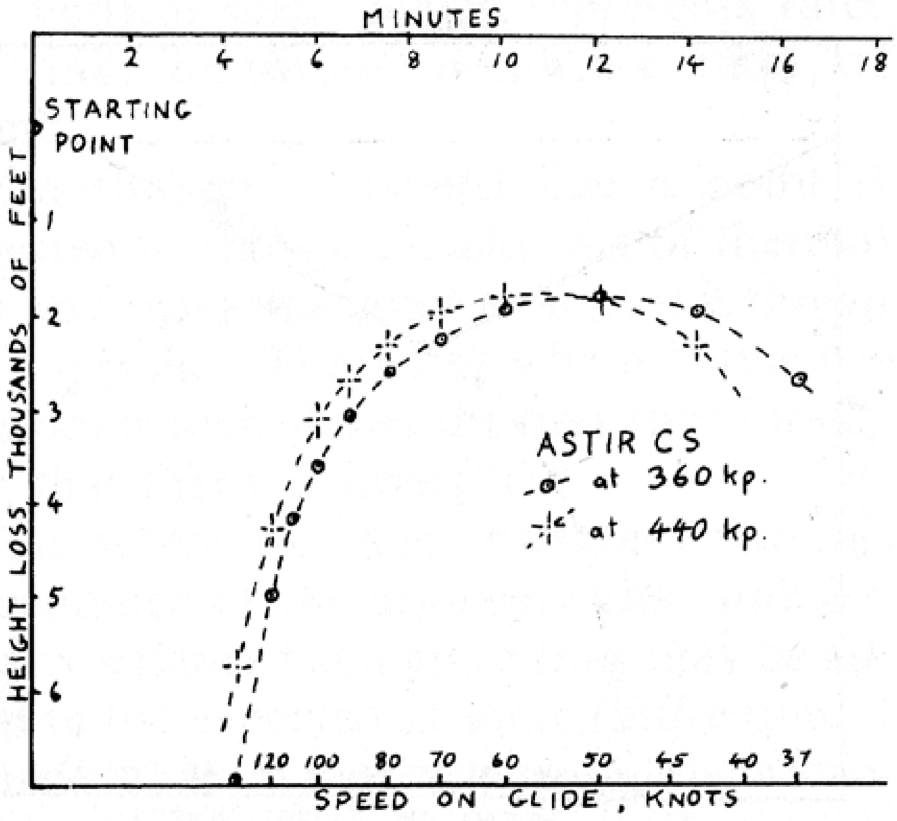

Fig 3. Thermal Interception Diagram for the Astir CS in the 10-mile case, showing the effect of water-ballast

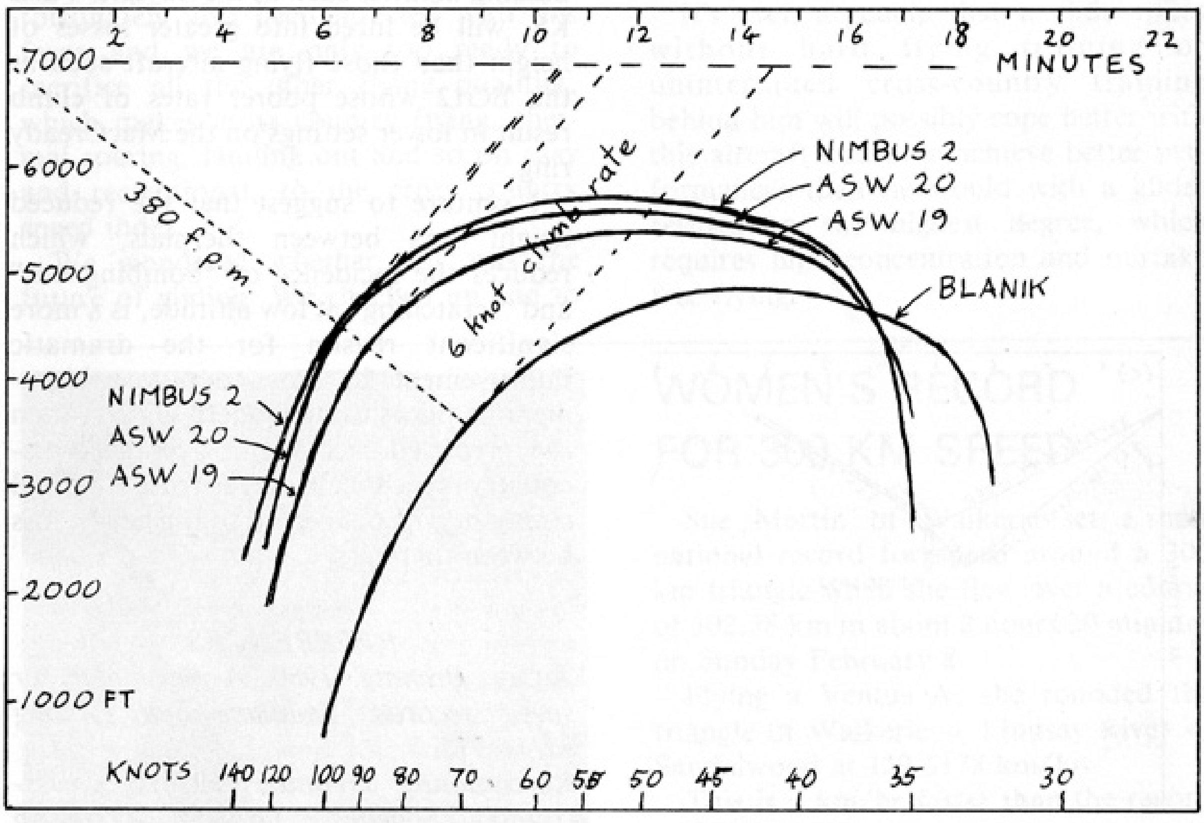

Fig 4. Comparison of the performance of several types of glider using the Thermal Interception Diagram

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country speed and on the height lost between thermals.

The two curves for the Astir CS with and without ballast are shown in Fig. 3: ballast moves the curve to the left and compresses it slightly.

Different gliders may be compared, as in Fig. 4, which shows such things as the very small difference between the inter- thermal performance of a Nimbus and an ASW20, and the large handicap under which the Blanik pilot labours.

The diagram has a particular bearing on an argument first put by Anthony Edwards (1964) and later publicised by Helmut Reichmann (1978), and discussed in correspondence in Sailplane and Gliding in April and December 1979, that speed to fly should be based not on average thermal strength, but on an estimate of the initial climb rate in the next thermal.

It is clear that if two pilots have left a thermal together, but one flies faster, at a higher ring setting, than the other, the faster flier can beat the slower only if, after arriving at the second thermal, he gets above the slower pilot **by the time he arrives.**

Once the slower pilot has arrived the two pilots should climb at the same rate as each other, and their relative positions will not change, regardless of the thermal strength after that moment.

The time between the arrivals of the two pilots at the thermal will be quite short. In the 5 knot thermal shown in Fig. 2d a pilot flying on a 6 knot ring-setting (90 knots) would have only two minutes, or five or six thermal circles, to climb through a pilot using a 3 knot ring setting (70 knots).

After this time the relative positions of the two gliders will depend on new developments and decisions, the previous inter-thermal speed no longer having any influence at all.

To take the case of a single pilot, having flown the glider at a particular ring setting, as soon as he has become established in steady lift he could, in

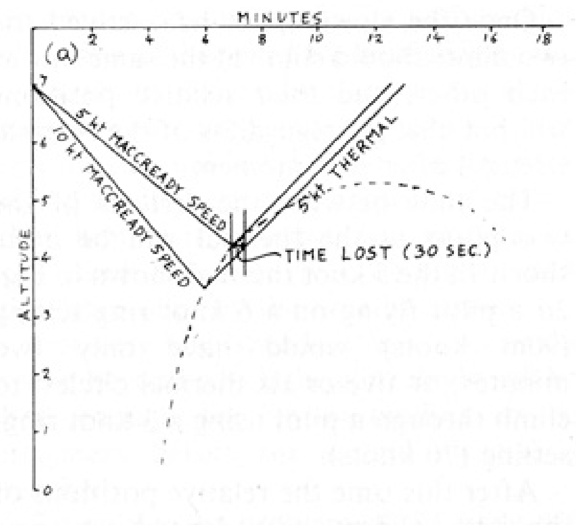

Fig 5a.

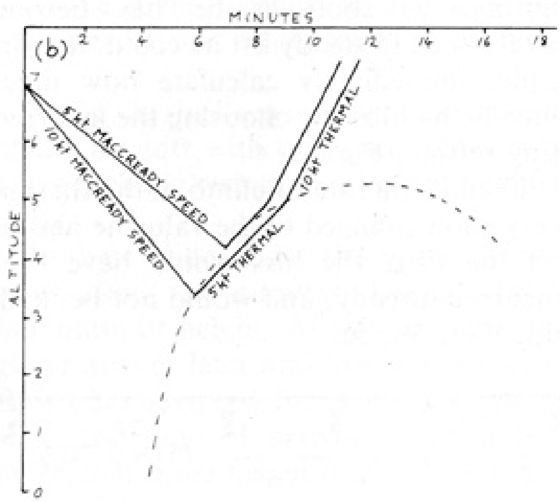

Fig 5b.

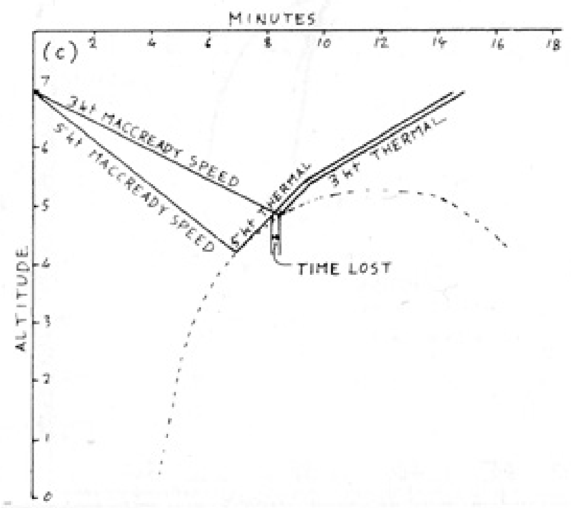

Fig 5c.

Fig 5. Time lost by incorrect assessment of the initial climb rate principle, immediately calculate how much time he had lost by choosing the incorrect ring setting, Fig. 5a.

Even if the rate of climb in the thermal very soon changed to the value he had set on the ring, the loss would have been incurred already, and would not be made up, Figs. 5b, 5c

The over-riding importance of initial climb rate does not invalidate the calculation of average cross-country speed given earlier (Figs. 2d, 2e, 2f). One must simply note that the rate of climb in the thermal is assumed to be constant, continuing at the initial rate all the way up.

The points on the thermal arrival time curve are relevant not only to MacCready speeds but also to altitude conservation.

Whereas the “best” speed is located by the tangent to the curve representing the actual thermal strength, this may, if the thermals are widely spaced, indicate a disastrous loss of height on the inter-thermal glide.

In Fig. 4, if each of the gliders shown is flown at the best speed for an expected 6 knot thermal, their respective rates of sink are almost identical: 380 feet per minute.

However, at this rate of sink the Blanik will lose 3400 ft. in 10 miles, which could well result in an outlanding, while the other types will have lost only 2400 ft. to 2700 ft. over the same distance.

Of course, the climb rates of the various glider types in the same thermal may well differ, leading to different ring settings. Ironically, pilots of those types of older glider that have outstanding thermalling abilities such as the Skylark 4 and K8, will be lured into greater losses of height than those flying aircraft such as the BG12 whose poorer rates of climb result in lower settings on the MacCready ring.

I venture to suggest that the reduced height loss between thermals, which reduces the incidence of “bombing out” and “scratching” at low altitude, is a more significant reason for the dramatic improvement in cross-country achievement by pilots using modern gliders, than the predicted increase in average cross-country speed calculated from thermal strength, without regard to the height loss between thermals.

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- Reichmann, Helmut, 1978. “Cross-country Soaring”, Graham Thomson Ltd., U.S.A. (English language edition).
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