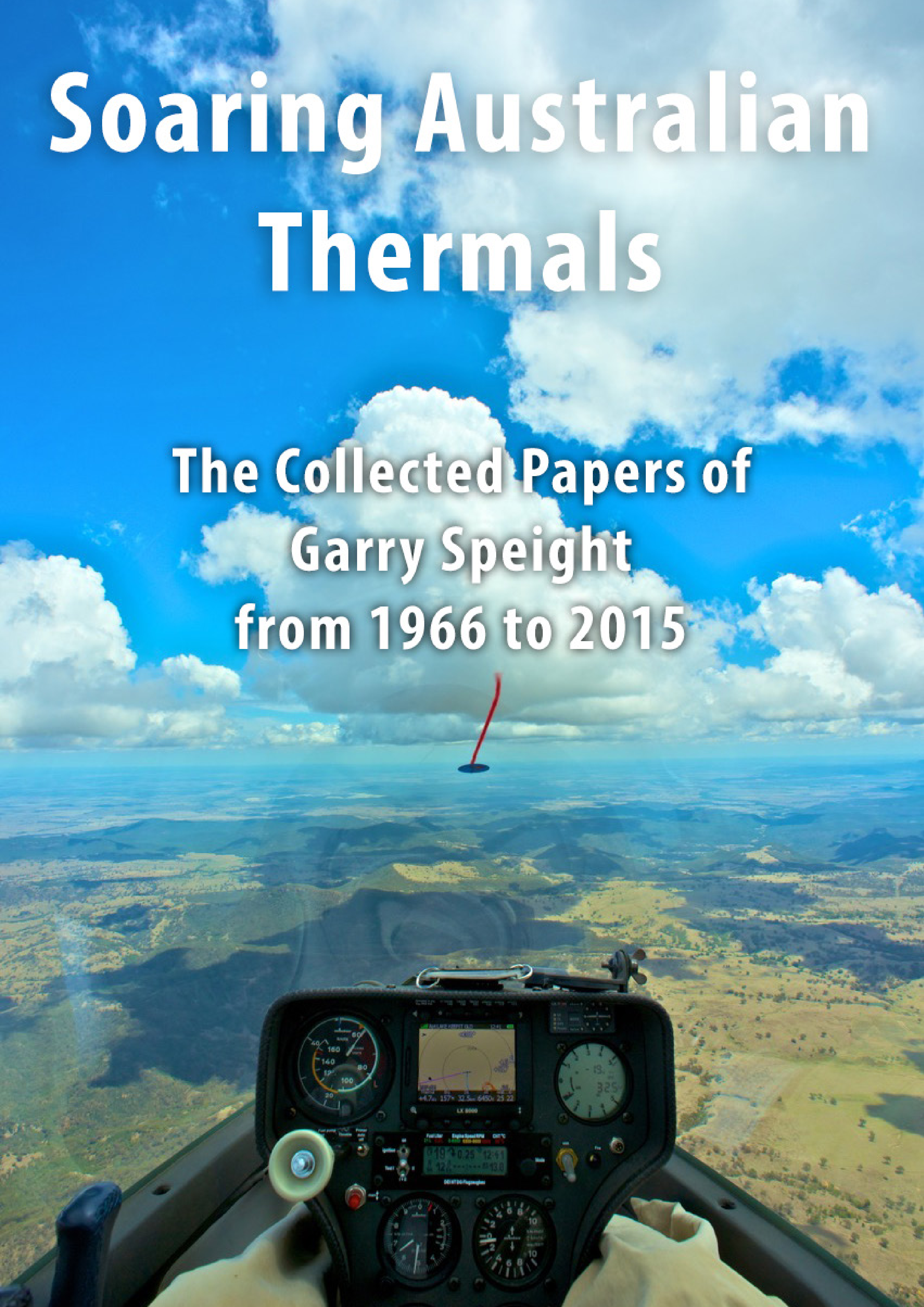

Soaring Australian Thermals

The Collected Papers of Garry Speight from 1966 to 2015

From the Editor

This is an edited collection of papers published by Garry Speight mostly in Australian gliding journals from 1966 to 2015. As you can see, the topics are diverse, always treated thoroughly and are often very erudite. Most of the early papers are still relevant and very useful to both beginning and experienced pilots. The Lake Keepit Soaring Club decided to make this body of work available to its members and to the gliding community by gathering them together, encouraging Garry to edit and comment on his work and by placing it on the Club's website.

The whole collection can be downloaded as one PDF or individual papers can be downloaded separately.

The project was initiated and managed by Graham Holland and prepared for digital publication by Oliver Brighton (Fotolly Media, info@fotolly.com). We thank Garry for his support, continuing interest and valuable input in preparing the papers.

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Graham Holland, Editor.
July 2015.

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Preface

During Garry's involvement with aviation, his contribution to gliding in general and the Lake Keepit Soaring Club in particular, has been nothing short of outstanding.

As well as his personal flying, Garry has contributed enormously as a coach, mentor, instructor, tug pilot and author.

Whilst the club and its members celebrated Garry's 80th birthday at a very special function in August 2014, it was felt that a more lasting record of his work should be made available to a wider audience.

Hence this small collection of the wit and wisdom of Garry Speight.

I am extremely pleased to commend this publication to you and I trust it will provide many enjoyable hours of reading pleasure.

Ian Downes
President
Lake Keepit Soaring Club

Introduction

By Garry Speight

The Articles

These are my articles about gliding written over the last 50 years. They cover aspects of gliding that I thought important. I am glad of the chance to bring them back into the light.

There are a couple of articles on unusual flights, and on Japanese gliding, but most are on soaring in thermals. Although I have battled mountain thermals and waves in New Zealand, and I have jumped from thermal to wave in Australia, I have written mainly about how to use ordinary Australian flat-country fair-weather thermals.

My writing is technical and academic, rather than creative; I write as I did as a scientist. If you find some of my articles hard going, please don't give up.

With the series "Thermals That Rotate" I made my work easier to read. At first, that series was a single long article. I asked for comment from a large instructors' panel and, except for two or three, their response was so negative that I shelved the project. On later advice, I broke the topic into four parts, made it simpler, and put technical notes at the end. As you see, the articles then brought a good response.

I hope you enjoy reading all the articles, even the difficult ones, and those that seem quaintly antique!

How did I get into this?

My parents' life in aviation

My father, Ernest John Speight ("John"), born in 1900, started flying DH-60 Gipsy Moths in 1934, soon after I was born. That was at Nelson, New Zealand, and he trained as a member of the Marlborough Aero Club, based at Omaka, near Blenheim. John was a surveyor/engineer's assistant, on the construction of Nelson aerodrome. He and my mother Emma ("Jo") hatched a plan that he would make a career as a specialist aerodrome engineer, for which earning a (ruinously expensive) pilot's licence would help. The plan worked! John was appointed supervising engineer on Woodbourne RNZAF Station, building it from green fields to completion from 1939 to 1941. Woodbourne was one of the Flying Schools that supplied thousands of pilots to the RAF for the war in Europe.

In late 1941, a week before the Pacific war began, John was sent to Fiji to supervise (as I believe) the construction of runways at Nadi ("Nandi") aerodrome so that four-engined aircraft could land there. The US Government agreed to pay seven million pounds as wartime "reverse lend lease". Within six months the New Zealanders had built two 7000-foot runways: "on budget, and ahead of time". That paid off: in March 1942 forty-eight Marauder high-speed bombers re-fueled at Nadi en route for Townsville and from there they attacked Rabaul. At Nadi Airport, these are the runways you see, but runway 02/20 was extended to 10,000 feet and concreted for jet aircraft twenty years later.

John's own flying career was cut short at 200 hours by a war-time ban on private flying. By then he had a commercial licence, and was flying the Miles Hawk and Miles Whitney Straight. He also flew some dual in RNZAF Oxfords and Harvards. When I took him up in a Kookaburra in 1974, I did not hand over to him until after the take-off, but he would have flown that perfectly too.

My mother, Jo, enjoyed flying. She passed a flight test for a flying scholarship, but there was no


At Omaka, 1937

money to continue. When her sister Pat married Captain Maurice Buckley, they had a celebrated "flying honeymoon". Uncle Maurice became C/O of the famed No.75 (NZ) Bomber Squadron RAF in 1939, and later an Air Commodore.

My childhood flights

Thanks to my parents, I started flying at the age of two years and nine months. Over Easter 1937 John and Jo took me (illegally) in the Gipsy Moth ZK-AEM from Blenheim (South Island) to visit relatives in some North Island towns including Gisborne. It was a distance of 900 km, including crossing Cook Strait twice, and took 10 hours flight time. Later (30/1/1939) when I was four, I had a five-minute joy flight in a Moth with John. Then, from the age of five to the age of ten I lived at RNZAF Woodbourne within sight and ear-shot of aeroplanes every day: the die was cast.

My training in aeroplanes

In DH-82 at Omaka, 1951

Governments, then as now, ensured a supply of pilots to fight in foolish murderous wars by sponsoring free flying training in an Air Training Corps. I was game. Living in Blenheim at the time, I took up my ATC flying scholarship with the Marlborough Aero Club in my father's footsteps. I began flying DH-82 Tiger Moths on turning 17, and soloed on 22/9/1951. The scholarship was carried forward so that, by the end of 1953, I had 50 hours in Tiger Moths and Auster Aiglet J5F's. Then I was due for three months of Compulsory Military Training, which included another 12 hours in Tiger Moths. My bored instructor gave me an inverted spin exercise.

Being still game, I volunteered to train in a "university course" of the Territorial section of the RNZAF. The Territorial training was full-on. We did the RNZAF Pilots Brevet ("Wings") course with the regulars, but we did it (with pay!) mainly in two university long vacations. The course was at Wigram, Christchurch, and included 200 hours of training in the North American Harvard (T-6 Texan, SNJ, a Wirraway cousin). The first long vacation was "Initial", coming to grips with the big machine by circuits, aerobatics, forced landings and navigation. The second long vacation was "Advanced" including night flying, instrument flying, formation, gunnery, and bombing.

After gaining my "Wings" I did about ten flights per month in week-ends with No.3 (T) Squadron, based at Wigram. The squadron was equipped with Harvards only, as P-51 Mustangs had been retired due to maintenance cost and crashes. The RNZAF tried to give us fighter experience with one training camp at Ohakea where we flew Dual Vampires for six hours. My active commission in the Territorials ended in November 1956, when I had a total of 368 hours in aeroplanes, and the whole system was closed soon afterwards.

Flying for the RNZAF, I did not need a pilots licence. I qualified for that decades later, in 1989 (on holiday in New Zealand) and 1991 (in Australia). I had thought I should make myself more useful by

With Rupert Brown at Canberra, 1962

towing at Lake Keepit. I found the tug aircraft more fun than Cessnas, but not much. I gave up in 2010, after 4740 yo-yo aero-tows and 1080 noisy hours in total.

Beginning gliding

In 1961 I was lured by an enormous salary to cross the Tasman to a research job with CSIRO in Canberra. I thought I might spend my wealth on an aviation hobby, but what? Cessnas did not appeal after Harvards. Sky diving seemed far too exciting and brief, and ballooning meant getting up early in the morning. At that date, I don't think practical hang-gliders, paragliders, trikes, ultralights or gyrocopters had yet been invented.

When Rupert Brown formed the Canberra Gliding Club I joined it. As Rupert was by far the best instructor I had ever had, he got me hooked!

My life in gliding

Operations check at Wagga, 1975

I have been very lucky to have flown gliders year after year since 1962. Neither my scientific career nor my family commitments were such as to keep me away. My thanks to bosses and spouses!

For 27 years, I flew only week-ends and holidays, doing 50 to 150 hours per year. I soon began instructing and competing, and later acting as an Assistant Regional Technical officer for Operations and as a coach at "Teams Challenge" events. These activities made me think about the theory and practice of cross-country soaring, which I have written about.

In 1989, I was made redundant at CSIRO. Fortunately, by then I had no family commitments, so I was able to go full-time instructing on a subsistence income. From then I flew gliders for more than 200 hours most years. In 1994, when I instructed for 420 hours, I recall thinking "I would fly better if I were more current!"

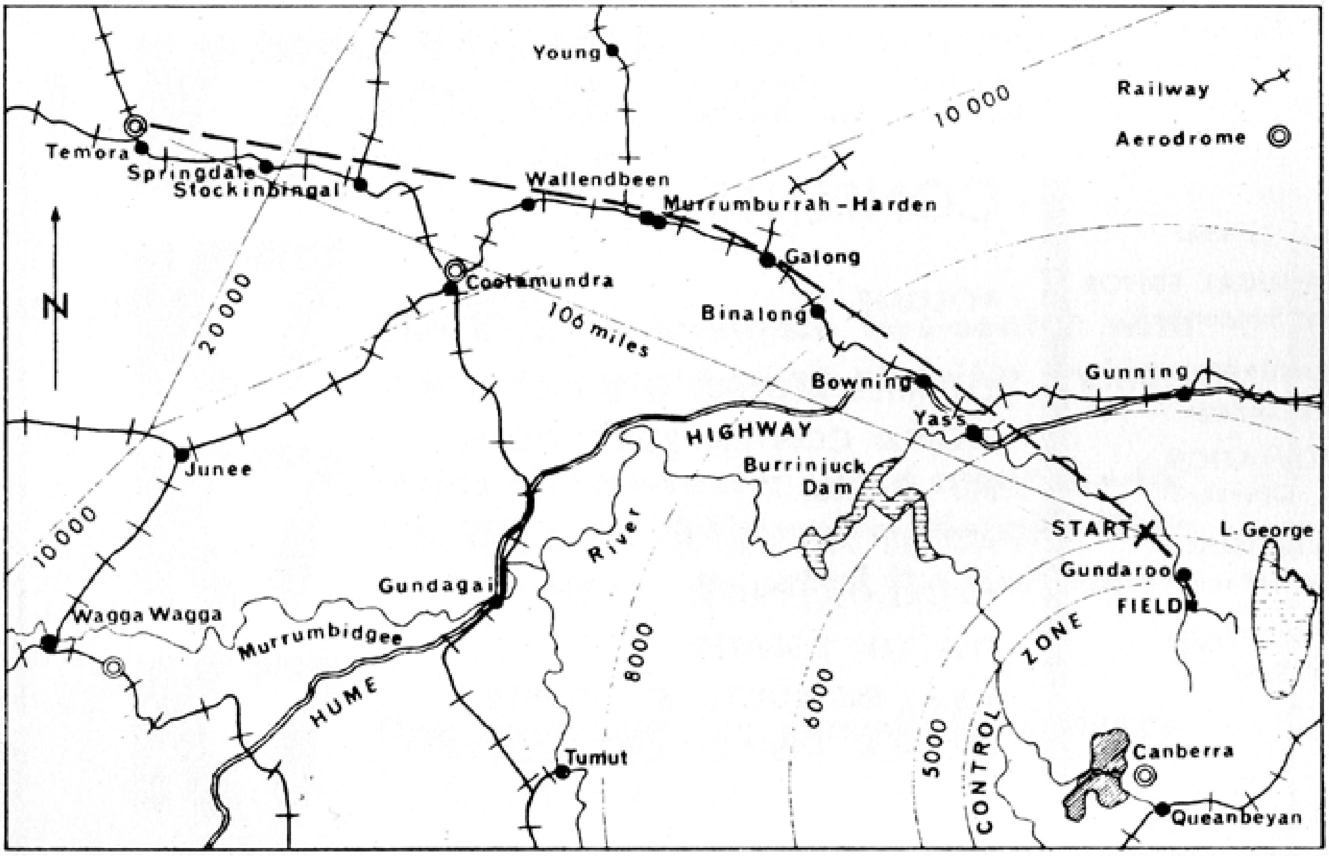
In the whole 52 years of gliding, I have flown 8850 hours in 15,800 flights. Of these, 1100 were cross-country flights, with a total distance of 234,000 kilometres - more than half-way to the moon. I competed in 60 Australian State and National Championships, but I seldom won.

Acknowledgment

I thank Graham Holland for the initiative for this collection, and I acknowledge the sponsorship of the Lake Keepit Soaring Club and technical assistance from Oliver Brighton.

212 Mile Record O & R

By John White



This first article was written by my friend and co-pilot, John White. I contributed the map and barograph trace.

Originally published in Australian Gliding, April 1966

When Garry Speight rang to ask if I would be interested in a cross-country flight as co-pilot in the Canberra Long-wing Kookaburra it didn't take me long to say yes. That evening, Friday January 15th, saw us poring over maps, looking at the list of Australian gliding records, and making sure that we would have all the necessary materials and launching crew.

We had to take into account the special difficulties in getting away from the club's field at Gundaroo, We are four miles inside the Canberra Control Zone and would have to begin by flying northwards to get clear of it, and once out we would not be allowed back in. Immediately outside the zone, landing fields are scarce, the only really satisfactory escape route being down the river to Yass.

Even on this route we would be restricted by the stepped base of the Control area which is 6000 ft. above sea level as far as Yass, giving us 4000 ft. of clearance above the valley floor. However, we are pretty well accustomed to flying under a specified low ceiling, and thought we might manage to get away, especially as Rupert Brown and Heinz Tietz had managed a 159-mile flight two weeks before. A light northerly was forecast, so we planned to head for Benalla for the 2-seater distance and goal record.

Saturday morning proved to be hot, with temperatures in the eighties at breakfast time. The forecast was now moderate north to northwest winds, which would make the trip to Yass more difficult. Furthermore, a front was coming up from Melbourne and was bound to beat us to Benalla. An out-and-return seemed to be indicated.

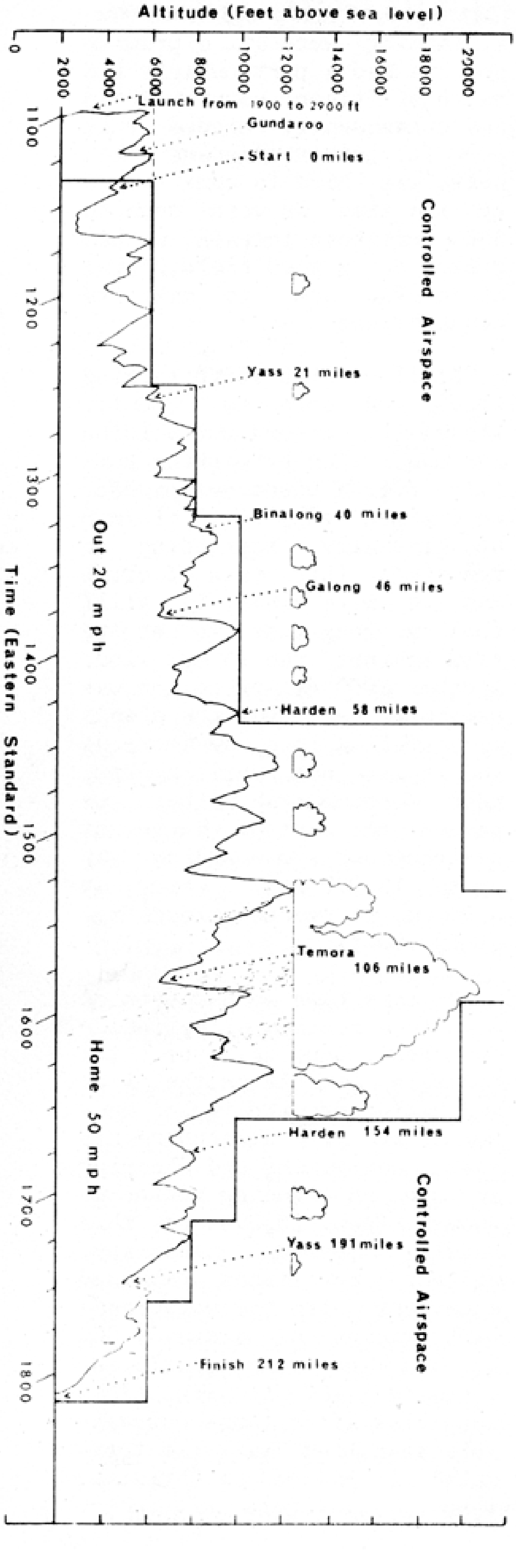
The record book said 86 miles; Temora aerodrome was about 100 miles and in line with the escape route, so we declared it, making sure that we also declared a point at the edge of the control zone as start and finish.

By 10.30 we had the glider on the strip complete with tie down kit, lunches, jerseys and maps. The barograph was installed and we had both checked that it was running. Air Traffic Control gave us a special clearance to 6000 ft. within the control zone and after a few frustrating delays, we were launched straight into a thermal at 11:05 a.m.

A climb rate of 500 ft./min reassured us and we quickly found ourselves up to our 6000 ft. limit. It was certainly disappointing to have to break off the climb with cloud base still several thousand feet above us. Anyway, we had soon made up the distance we had drifted back while thermalling, and were making ground towards Temora. Two more thermals took us out of the control zone and then we hit a flat spot. Fields suitable for a landing were at a premium and we had a particularly bad patch of 'tiger' country ahead and consequently needed that 6000 ft. before crossing it. Lift was hard to come by and by the time we were down to 2000 ft. above terrain we had picked out a good field, hoping of course not to make its acquaintance.

Still no lift worth talking about and down to 700 ft. above the ground but holding our own. Then by working some lift over a burnt out paddock we changed this to 50 ft./min up, gradually increasing to ten times this rate of climb and we were clear. It still took a long time to get to Yass against the 15 mph wind. Another 2000 ft. of height was available here but the clouds were still a long way above us and it was not until 2.30pm, near Murrumburrah, that we passed the last of the height restrictions and wound our way up to 12,000 ft. Later, at 3.30 pm, we reached cloud-base at 12,400 ft.

By this time we had settled down to a routine of half-hour 'watches', handing over the controls exactly on the hour and half-hour, the 'idle' member of the crew stretching his legs, navigating and keeping an eye on landing fields although from



12,000 ft. this hardly seemed necessary. Weather conditions remained excellent with thermals regularly giving us a steady 800 ft./min and one memorable one a steady 1200 ft. min. (This was bliss after those unspeakable so-called "Waikerie thermals" I endured at Christmas time…G.S.).

Once, at over 12,000 ft., we met an eagle, but we soon lost sight of him and didn't see whether he flew into the cloud or not. We were quite warm in our shirts and shorts, so I don't think the temperature could have been much below 60. The clouds were building up though and we were rudely shaken out of our routine by the sound of a machine gun going off just in front – actually it was a light shower of hail but it certainly came as a surprise.

About this time we decided to spend a bit of time below 10,000 ft. in case we were getting too little oxygen and with this end in view flew straight through a couple of thermals. Rate of sink was fairly high but this was no surprise considering the booming thermals we were getting. One bonus was that at 12,000 ft. our I.A.S. of 70mph became a T.A.S. of around 90mph.

And so to Temora; down to 7000ft. to get good photographs (the name fortunately being written on the hangar roof). Then up again to cloud base and set course for home. It seemed we were now in a frontal zone, for the wind was southerly and Cu-Nims were developing above us with rain pouring out of them in patches so we diverted round them to miss the worst of it. Our hopes of actually getting back the 106 miles to Gundaroo were fairly dim as it had taken five hours to get to Temora and it was 4 o'clock by this time. Anyway we pressed on, finding long spells of zero sink alongside the Cu-Nims and all the thermals we wanted.

We were soon back in the westerly wind and the first fifty miles home were covered in fifty minutes. By 5:30 Yass was underneath us, but there were no more cumulus clouds ahead to mark the thermals, and the towering frontal clouds behind were casting a great shadow that seemed certain to kill the lift we needed for the last twenty miles. In addition we were back inside the circles around Canberra control zone and had to leave our lofty position and descend to more mundane altitudes. Ten miles to go and a thermal as smooth as silk from a hillside facing the setting sun and I knew we had it made. And so it proved.

We arrived over our finishing point just north of Gundaroo and had plenty of time to pick out the best of the available fields. In to land, swerve a little to miss a sheep, and silence.

Outside it was still over 90 and we found out later that Canberra has had its hottest day for years – just topping the century. It was 7 hours since take-off. We climbed out rather stiff-legged and while Garry pegged the Kookaburra down, I telephoned in from the nearby homestead. After the retrieve crew arrived there came the job of getting the Kookaburra to pieces and trailering it back to our field. After that the barograph had to be unsealed by an official observer, then there was time for a long cool drink and finally, at midnight, something to eat.

It was not until after the flight that we found out that we need not have gone nearly so far to beat the existing Australian record of 86 miles. We had mistakenly understood this to be the one way mileage whereas, of course, it represents the round trip mileage and we were in the happy position of more than doubling the existing record, setting the peg at 212 miles, subject to official ratification.

High Wind, Rough Country & Airspace Limits

By Garry Speight

This 1967 flight in a 13-metre ES59 Arrow still provides me with an anecdote to use in cross-country briefings. For the outlanding, I was so nearly caught out by the small size of paddocks near towns, and by the wind for landing being different from the wind at height.

Originally published in Australian Gliding, December 1968

This is the story of a flight that was neither long nor successful, but most enjoyable nevertheless. The idea was to fly from the Canberra Gliding Club's field at Gundaroo to Camden Aerodrome, This is only 107 miles in a straight line, but the gorges of the Wollondilly to the north and the Shoalhaven to the south encourage one to stick close to the Hume Highway; this adds about five miles, and the dictates of Air Traffic Control add another three, making 115 miles in all. The terrain is nearly all above 2000 feet, and the base of the control area is at 6000 feet or lower for more than half the distance. In general the country is pretty inhospitable, and "crossing the Blue Mountains" by glider had apparently not been achieved since the flight that Fred Hoinville described in "Halfway to Heaven". Since my flight Allan Yeomans has made the crossing from east to west.

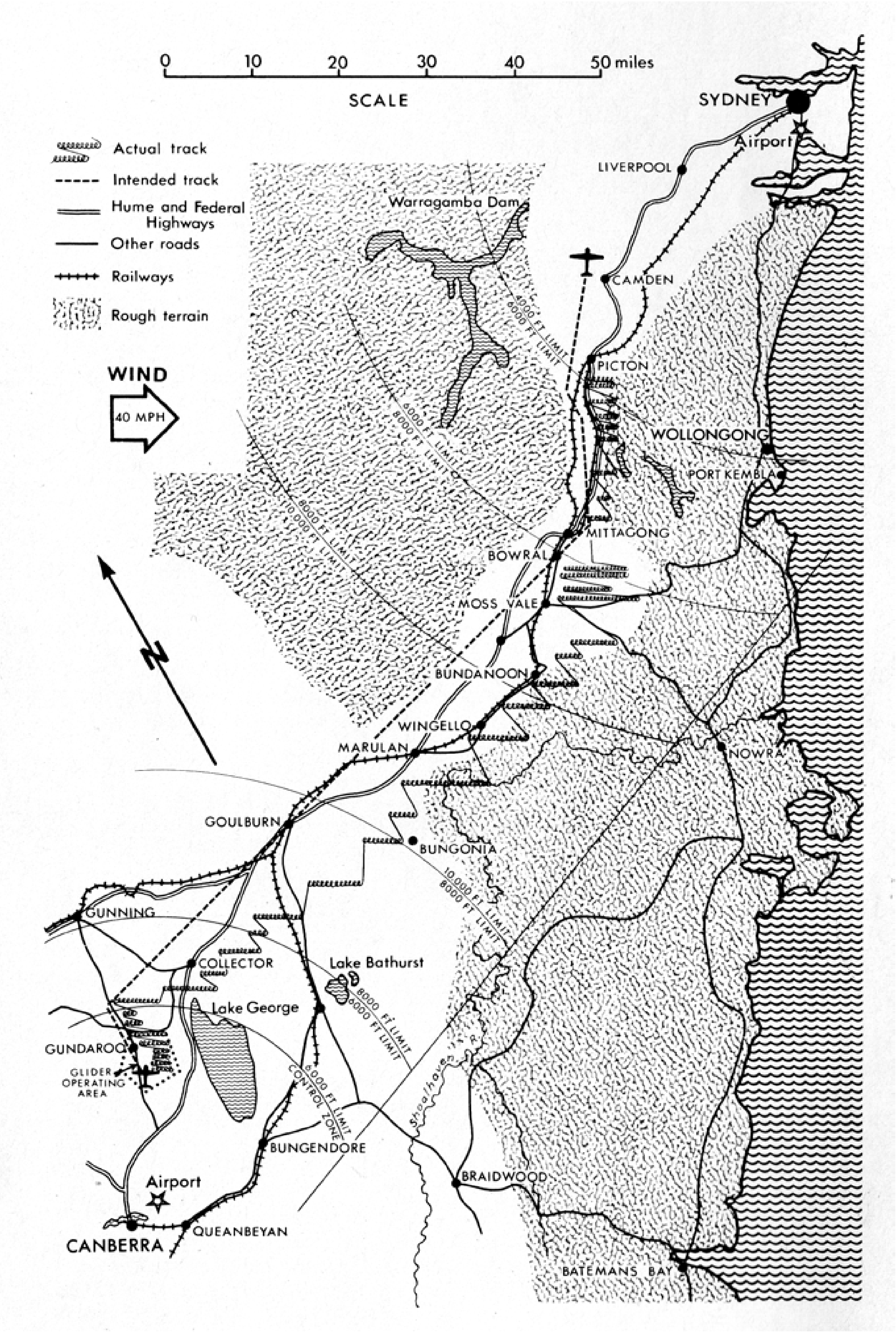
Over the 1967 Christmas holidays our Kookaburra was away at the National Championships, but the Arrow, recently bought from the Barossa Valley Gliding Club, was available, so I set off on December 30th for Gundaroo, with Helmut and Bridget Kaltenthaler very kindly crewing for me. The forecast (which proved accurate) was as follows: Wind NW 25 kt at 3000 feet, NW 35 kt at 5000 feet; cloud 4/8 Cu with showers, increasing Ci and As; temperature 80°-90°. The high wind was rather discouraging, but the convection was obviously strong enough to make it worth trying and there would be a tailwind component of nearly 20 mph. I determined to do two things - stay upwind of the Shoalhaven gorges and get well upwind of track where the greatest altitude was available near Marulan.

At midday I was strapped in and Bridget was lifting the wing up and down to signal, "take up slack", but we were getting no response. Then Helmut drove up from the winch end. He had rung Canberra tower, 20 miles away, for permission to launch but the controller had not granted it, "There is a dust-storm", he had said, "Visibility is less than 100 yards". "But we're not having a dust-storm", I said, "I told him that", said Helmut, "but he just said 'stand by one hour'". For the next 55 minutes I sat with both legs on one side of the control column, holding a wing down, and just waiting while the cloud streets formed and re-formed overhead, I suppose the dust-storm at the airport was generated at the suburban development work in Belconnen.

Finally permission was granted with the stipulation that I must either land or leave the control zone by way of the Yass River Valley before 1400 hrs. The launch took me from 1800 feet to 3400 feet, than a thermal took me, at 400 feet per minute, to 6000 feet at the expense of a three-mile drift down-wind. My prescribed track to clear the control zone was obliquely up-wind, so I had quite a task on my hands. In fact, I finally left the control zone at the limit of my allotted time and only 700 feet above terrain. Four miles in an hour!

The next fifty miles ought to have been easy, what with the base of the control area getting progressively higher and the wind only 45° off track. However, the drift in thermals was astonishing, as the wind speed was approximately 40 mph and my achieved rate of climb averaged only about 300 feet per minute, so that a 3000-foot climb entailed a seven-mile drift. "Track" became a wistful hope, a mirage on the western horizon. I had no fixed policy about which way to go when a thermal passed upwards into

High Wind, Rough Country & Airspace Limits



forbidden airspace. Sometimes I headed directly towards my intended track and at right angles to it, which, in retrospect, seems to be the wisest course when one is much too far downwind, but mainly I was concerned with flying towards active clouds, or towards more hospitable country, I would have benefitted by flying at the maximum permitted rough air speed (85 mph), but, frankly, I was scared to exceed 75 mph in such turbulent conditions.

At three o'clock I was getting an uncomfortably close view of some barely-landable paddocks near Bungonia. When the essential thermal finally turned up I didn't feel much better, for if I worked it I would be carried straight out over the awe-inspiring crags and chasms of the Shoalhaven gorge, 2000 feet deep. The variometer hit the "up" stop so up I went. After the first few hundred feet it was clear that I could glide out to open country at any time, but that didn't quite dispel my anxiety as the cliff-top quarries of South Marulan passed below. This time I was able to follow the thermal to cloud-base at 9000 feet, the base of the control area being 1000 feet higher. (This particular bit of uncontrolled airspace has since been seized by the Royal Australian Navy). At this point I was just crossing the Shoalhaven River for the second time, a couple of miles north of 'Tolwing' homestead. I imagined myself landing there, finding nobody home and taking a week to walk out to the coast! As the horizon started to disappear into cloud I set off northwards, refusing to circle until I reached the railway near Wingello. From there to Moss Vale I managed to beat as far upwind as the railway after each thermal. The views from higher altitudes were superb, with the Kangaroo Valley in the foreground and Nowra clearly visible in the distance. I thought of dropping in on the RANGA boys - I could have been on the runway at HMAS Albatross in ten minutes flat, - but that would have muddled up the retrieve.

At Bowral the base of the control area stepped down to 6000 feet from 8000 feet, so here was my last good opportunity to beat into wind before the reduced ceiling forced me to spend a larger part of my time seeking and centering thermals. Unfortunately the "climb ratio" of one in eleven that I was achieving while thermalling was no greater than my glide ratio when flying upwind. Twice my determined dash into wind ended up with a struggle to work the ragged lower fringe of the very same thermal I had made my previous climb in! I reasoned that if I did this often enough I would eventually miss out on the thermal and end up on the ground without achieving a yard of progress, so I gave up and pointed the Arrow straight towards Mittagong aerodrome where, at ten minutes to five, I regained track for the first time since takeoff.

From here on my prospects of success were poor, for the thermals were weakening, my intended track was slightly into wind, and useful fields for landing were decidedly sparse.

I zig-zagged, along, keeping an eye on one possible landing field or another in the populated area near the railway line, and fighting narrow turbulent thermals. One thermal took me directly over the Nepean Dam at 5800 feet. Fifteen minutes later I found myself at 5300 feet just one mile further north. Progress!

A few minutes before six o'clock, as I approached Tahmoor, I passed under yet another step of the control area, making my ceiling 4000 feet. This was the beginning of the end. Camden was in sight too!

It was time to plan a landing. I was about 1,000 feet above the ground and there wasn't a whisper of lift. Two paddocks looked reasonably suitable. But the nearer one seemed to be quite strongly sloping and also had a cow in it, so I cruised over to have a look at the other about a mile away. This one appeared to be large enough, flat enough, smooth enough and free of obstructions. I planned an approach over a patch of forest and directly into wind, but this looked a bit short as I got lower, so I switched to run down the greatest length of

High Wind, Rough Country & Airspace Limits

the field, regardless of the wind. This approach was clear of the trees so I was able to come in quite low. Then there was a long, long float and a seemingly endless landing run, finishing up 30 yards from the far fence.

I got out. There was not a breath of wind. The field was much smaller than I had imagined - I later paced it out as 250 yards long - and the trees were over 100 feet high. I could never have got in on my original approach. I was in the very heart of Tahmoor, between the store, the church, and the turkey-processing works. In fact, I was in the backyard of Denfields' well-known antique furniture cottage on the Hume Highway.

After pegging the glider down I strolled across to the telephone box and rang my wife, Jane, to give my landing report. She told me that Helmut and Bridget were about an hour behind. As I settled down to wait for them a car pulled up and Harold, Mac and Roger Randall, got out. They were on their way home after a few days at the Nationals, of which they gave me up-to-the-minute news, It was a real pleasure to have their company and their assistance for de-rigging the Arrow when Helmut and Bridget arrived.

For me this was a very satisfying and memorable flight despite the fact that no conventional attainment-distance, goal, speed or altitude - could be recorded. Perhaps I made a virtue of necessity in handicapping myself with bad weather, bad terrain and crippling altitude restrictions, but in gliding there are no absolute standards, and both the struggle and the achievement are real only to the pilot himself.

The proud owner with his brand new Astir CS, 1977

Canberra Control Zone Extension Reversed

By Garry Speight

Originally published in Australian Gliding, August 1974

Many glider pilots will have wondered how the recent NOTAM H.O. 16 of 25 April 1974, which sets out extensions to the Canberra Control Zone, affected the gliding clubs at Canberra. Well, it was a kick in the teeth. As is well known, we operate at Currandooley under an airspace limit 1800 ft. above the ground, but we have a safety valve in that, whenever Lake George is fairly low and the exposed bed of the lake is dry enough, we can ferry our aircraft 13 miles to a locality at the north end of the lake, one mile outside the control zone. Here we not only enjoy 3800 ft. of airspace but also soar for miles along a 900 ft. escarpment in every easterly breeze. The site is so attractive we did 60% of our flying from it last summer. The Control Zone extension took from us both the airstrip on the lake bed and the greater part of the escarpment.

Feeling slighted, we wrote on 1 May a strongly-worded protest to the man at the top, Mr. R.D. Phillips, Deputy- Secretary of the Air Transport Group, pointing out the drastic effect of the NOTAM on our operations and implying that our 1600 aircraft movements in one summer might be hard to match in other aircraft movements that might be facilitated by the Control Zone extension. We concluded by asking for a meeting with a senior officer to discuss the matter. Some of our club members, who felt that the Air Transport Group was intentionally leaning on us, predicted that their reply would simply reiterate the reasons for the Control Zone extension given in the NOTAM and would conclude, with regret, that we would have to do our gliding elsewhere.

The actual outcome was very different. First, we had a letter dated 29 May and personally signed by Mr. Phillips stating that a further investigation of the airspace tolerances required to protect instrument descent procedures was being carried out to determine whether modifications could be made to the Control Zone boundaries to exclude the areas that we had mentioned. In the meantime we could expect to obtain release of the airspace almost at any time by telephoning Canberra Control. A second letter from the Air Transport Group dated 7 June said that, by requiring DME as an integral part of the Runway 17 VOR instrument approach to land procedure, it had been found possible to reduce the control zone to its previous boundaries, and that AIP amendments would be made accordingly!

Naturally, we are delighted with the outcome of the correspondence. Our enjoyment of the lake floor site itself will have to wait for the weather to improve, but we are very encouraged to find that, in this case, the Air Transport Group's policy of first priority for commercial passenger traffic has not been interpreted to mean absolute priority. A way has been found to accommodate gliders as well as airliners in an area of intense air traffic.

In our reply thanking the Deputy Secretary for his courteous consideration of our case we concluded with a regret that no machinery existed that could have brought our needs to the attention of the Air Transport Group before the airspace change was promulgated. This is a point that we, as a Gliding Federation, must put as often as we can. As Alan Patching wrote after Pirat Gehriger's talk on airspace to Australian aviators in February, we should be actively pursuing a case for the setting up of a Federal Airspace Committee on which all users have a place.

All airspace use is associated with centres of population: the larger the population the greater the potential density of air traffic, including gliding traffic. While the total traffic density was relatively low, it was possible for the glider pilot to accept the position of bottom man on the totem

Canberra Control Zone Extension Reversed

pole because there were still some bits of sky near cities that nobody else wanted. Now the heat is on. Since gliding clubs serve a community need for recreation and that recreation is needed most of all by people who live in cities, we have an excellent case for insisting that gliding should not be forced out. To submit to pressure to relocate gliding sites further than one or two hours travel from major cities is to accept that gliding is the preserve of an elite who have plenty of time and money.

Each club with airfield or airspace problems sees its own case in isolation, and tends to fight a rearguard action against bureaucratic edicts. We must pool our resources, plan a strategy on recreational use of airspace, and insist on a voice in negotiations at both national and regional levels.

Garry Speight in his Astir CS at Collector near Canberra, 1978

Nihon No Guraidingu (Japanese Gliding)

By Supeito Gari (Garry Speight)

Originally published in Australian Gliding, November 1980

I arrived in Japan at the end of March last year for six months research at the Japanese Geographical Survey Institute, located at Tsukuba Science City, a New Town on the Kanto Plain 60 km northeast of Tokyo.

After a few weeks settling in, I started to explore the possibilities of gliding in Japan. Since driving in Japan is not very convenient, I didn't buy a car, but did my travelling by push bike.

Hearing of gliding activity at Otone, about 30 km south of Tsukuba, I set off one Sunday and, three hours later, after some false leads, arrived at the Otone private airstrip where I found the Japan Motor Glider Club operating a fleet of three Fournier RF-5's and an RF-4. It was refreshing to find some kindred spirits, even if a little bent towards powered flying, and I accepted the offer of a dual flight, though I was rather bemused by the price, 10,000 yen ($40) for 35 minutes. During the flight 1 turned the engine off three times, but there was no lift to be found, and we returned, to spend seven minutes doing a vast, complicated circuit pattern, beginning at 1500 ft., as dictated by the pattern of the powered traffic, and navigating by fixed reference points on the ground. However, some of the pilots I met that day had valuable information about gliding fields

The Keihin Soaring Club Blanik with club members, including the president, Akiyama, in the centre, and CFI Sakai, on the left.

Nihon No Guraidingu (Japanese Gliding)

and contacts in the gliding movement, so I felt the effort had been worthwhile.

The following week I set off for Sekiyado, also 35 km away, which I had learned was a gliding field run by the Japan Aeronautical Association. I had an introduction to Mr. Sakai, C.F.I. of the Keihin Soaring Club, and was able to get a dual flight in a Blanik with him.

I subsequently joined the Keihin Soaring Club; its name indicates that it is the Tokyo-Yokohama soaring club. "Kei" is what the name of the letter To is called (a la Lewis Carroll) and "Hin" similarly refers to the letter Hama of Yokohama. I hope that is quite clear?

The K.S.C. is based permanently at Sekiyado, which is only 40 km north of Tokyo, sharing the site with a number of university gliding clubs, some of which operate at more than one site. The club is the only non-university soaring club in the Tokyo area except for the Japan Gliding Association, which operates from Itakura, 20 km further north.

The airstrip at Sekiyado is situated in the flood-channel of the Edo River, and is about 1500m long and 150m wide. The width varies a bit depending on how successful the club members are at keeping the grass down. Usually two winches are running at the same time and there is a Super-Cub on hand for aero-tows. The Keihin winch is an impressive monster, truck-mounted with fixed hydraulic jacks, and a 220 hp 10 litre diesel engine out of a road-roller! Because of the flood hazard, all the Sekiyado gliders are towed over the top of the 10m high flood bank to be de-rigged and stored in a single hangar beyond the bank. Near the hangar there is a clubhouse, a bunkhouse, equipment sheds and car-parking space, but only one of the sheds is for the exclusive use of the K.S.C. During my stay, the club bought a $200 un-registered mini-bus for use as a field office.

The club fleet consisted at that time of one Blanik, claimed to be the last one produced, one Ka8, and one H 23-C. The H 23-C (Aichi-ni-san-shi) is a Japanese- designed 2-seater built by the Hagiwara Company, resembling some Schleicher design earlier than the K-7. Its role in Japan is like that of the Kookaburra in Australia. For me the H 23-C was the most interesting glider in the fleet, and it became a joke that if the H 23-C didn't get rigged Supeito-san would want to know why. When I flew it solo, I got the type conversion signed by the designer himself, Isao Horikawa.

The K.S.C. had ordered the first production Nippi Pilatus B-4, which I saw on the stocks at the Japan Aviation Company (Nippi) factory at Yokohama. Delivery was repeatedly delayed, notably for flutter testing which, I understand, may never have been carried out on the Swiss-built aircraft. A number of K.S.C. members are employees of Nippi. Ironically, the company also makes fiberglass boats, but is not interested in putting its aeronautical engineers on fiberglass work because it is not relevant to possible contracts on airliners or military aircraft. Nippi built a prototype motor-glider, which is currently out of service awaiting a more suitable motor.

By now I believe the K.S.C. should have taken delivery of their B-4, and I have heard that they also have a Jantar. With about 70 members sharing three gliders at the time of my visit, there was a lot of waiting around for flights. On the other hand, there was seldom a shortage of people for rigging or ground handling, and the aircraft were kept in beautiful condition.

Other clubs at Sekiyado had similar aircraft, Blaniks, H 23-C's, Ka8's, some superb Ka6's, Schweitzer 1-26's, Club Libelles, Astirs and a Twin Astir. Another quantity-produced Japanese 2-seater is the Mita, which looks exactly like a grown-up Briegleb BG-12. Its performance is probably better than that of a Blanik, but it is said to have ill coordinated controls and a tendency to spin.

My flying career in Japan was undistinguished, due to the problem that a gliding license is required in Japan and I could not produce an actual license from Australia. All my other documentation left the Civil Aviation Authority officials unmoved (and visibly inscrutable too). The argument is not completely over yet, and I have had a lot of help from G.F.A. Secretary Mike Valentine and the K.S.C. President Takehiko Akiyama, both of whom regard it as a matter of principle. In the meantime I took the medical and got a student pilots license, which at least permitted me to go solo, but not to instruct.

While doing my dual training, I flew with each of the English-speaking instructors of the club, and I formed many friendships. The club spirit was equal to the best I have seen in Australia due to the traditional Japanese togetherness feeling. Operational efficiency and fumbles were very much the same as in Australia. Like other Japanese sporting clubs, the K.S.C. operates

An Astir being tied down overnight during a regatta at Sekiyado gliding field, Kanto Plain, Japan. An H 23-C is being towed over the flood-bank for hangarage.

only on Sundays, because most people still have to work Saturday mornings, and continue into Saturday afternoon if there is a rush job on. The fact that the aircraft are idle on Saturdays is, I think, one of the main causes of the high cost of gliding in Japan. The K.S.C. fees in 1979 were:

Joining Fee	$200
Monthly Subscription	$ 10
Flying, per minute (minimum charge $6)	40c
Aero-tow to 2000 ft.	$10
Winch tow	$2

High cost is not the only deterrent to an aspiring Japanese glider pilot. Everything else is against him too.

Airspace

Control Areas in Japan normally have bases at 1500 ft. above surface, and 650 ft. above surface within 20 n.m. of each airport. About 90% of the land area of Japan lies under Control Areas. Nearly all the rest is under military (sorry, Self Defense Force) training areas.

Flight in controlled airspace is not permitted without V.H.F. radio on A.T.C. frequencies. Furthermore, flight planning and position reporting on A.T.C. frequencies are required for all flights beyond 5 n.m. from an aerodrome. Gliders are not yet permitted to carry V.H.F. radio, only 27 Mhz. Another potential airspace conflict resolved!

So far as I can tell, most clubs operate under some sort of special dispensation. At Sekiyado, the site is within a “Civil Training and Testing Area” extending from the surface up to 2000 ft. so training flights are permitted to 2000 ft. within 5 n.m. of the field. It has been agreed that flights **other** than training flights may be made to 5000 ft. after a telephone check has established that there is no traffic on Shimofusa Air Base.

My friends believe that approval for gliders to carry V.H.F. radio will soon be granted, and they are confident that cross country flights will then be permitted. Japanese controllers do not undertake to provide separation of all traffic in Control Areas as their Australian counterparts do.

Terrain

The terrain in Japan is about as bad as it could possibly be for glider flying. Eighty percent of the country is mountains, with practically no slopes lower than 30°. The rest is either cities or paddy fields. The paddy fields are smaller than Australian housing blocks, and are surrounded by banks and ditches, so they cannot be recommended for out landings, Furthermore, they are flooded in summer. Only Hokkaido, 800 km north of Tokyo, has any significant number of larger dry fields (precisely 250 m long; that would smarten up your spot landings!). The one possible location for gliding fields has been exploited by the Japanese enthusiasts. Every major river is bounded by flood-banks 5 to 10 m high. These banks must be rather widely spaced to contain very large floods, leaving between the banks a broad strip of land that is not suitable for building houses or growing crops. It is used for recreational purposes such as baseball diamonds, golf courses, and gliding fields, including Sekiyado. If A.T.C. clearance could be obtained, one could fly rather extensive cross-countries relying on the cleared open spaces along the major rivers, and on civil aerodromes and the golf courses that are situated on higher ground.

Weather

The weather around Tokyo varies a great deal from day to day and from hour to hour but, in general, it rains all through the summer and autumn, which are also very hot. The rain and low cloud-base, combined with the farmers' custom of flooding the fields, dampens the prospects for soaring. The air is rather unstable though, and there are often strong thermals between the showers. Just as in Europe, it is a problem on many days to see the cumulus clouds through the smog. During the winter, I am told, there may be some soaring, but operations are limited by extreme cold, snow, and high winds blowing from Siberia.

Social Attitudes

The Japanese gliding scene appears to be dominated by university gliding clubs and by university old-boys' gliding clubs. This follows from the well-known Japanese attitude of loyalty to one's own family, school, or company. To belong to a club or organisation that is independent of these groups presents a problem of divided loyalties to a Japanese. This not only limits the membership of independent gliding clubs, but also inhibits cooperation between clubs in the Japanese Gliding Association, making it rather ineffective, and unable to present a united front in its dealings with the Civil Aviation Authority, which controls glider pilot licensing and glider airworthiness as well as airspace use.

For the dedicated glider pilot, the frustrations of gliding in Japan can be bypassed by going overseas: the problems about this are time and expense. Time is a problem because, even though many people get three weeks leave a year, it is not the custom to insist on taking it all, or on taking it at a time convenient for the person rather than the company, especially for an activity that the company does not support!

As to cost, the Tokyo-Sydney air fare in 1979 was, at $1400, probably the most expensive per km in the world, and tickets bought in Japan cost 15% more than they do here! Some of my friends travelled to Estrella, Arizona on a package deal that included glider hire and accommodation for less than the airfare to Australia! However, they weren't very impressed with flying Schweitzer 1-26's. I met a number of people who had been to Waikerie or Narromine and who felt that it had been worth the expense. Others are planning to come as soon as they can. They have a saying: "For gliding, Japan is Hell; Australia is Heaven!"

Towards the end of my stay, Mr. Sakai asked if I would like to earn my "C" badge, because he doubted if any foreigner had ever done so in Japan. In due course I qualified, so on my last day I was presented with "A", "B", and "C" certificates, with badges marked "JA". The club also gave me a model of an H 23-C with the same registration letters and paint job as the one I flew.

Two schemes have come to mind to build

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Isao Horikawa competing in the NSW Gliding Championships at Narromine with Shoichiro Sakai, our translator Pauline Kent and Garry Speight spectating

bridges between gliding enthusiasts in Australia and Japan. One is that, if the Japanese manage to establish a cross country school, which could conceivably be done on Hokkaido, Australian instructors with racing experience might go there to instruct in the northern summer. The other is to encourage the participation of Japanese pilots in Australian State Championships.

This second idea was prompted by hearing someone say that the Japanese are disturbed to realise that they do not now have any pilots capable of representing Japan in the World Gliding Championships. This is basically due, of course, to the near-impossibility of practicing cross-country soaring in Japan, but even when Japanese pilots go cross-country in Australia or elsewhere, they practically never have a chance to compete in races. As a first step, after checking with the N.S.W.G.A. President, I wrote to the Keihin Soaring Club, proposing that a pilot should share my Astir with me in the forthcoming N.S.W. State Championships. I am happy to say that Isao Horikawa intends to come, and that Shoichiro Sakai hopes to come as crew.

Cheaper Cross Countries

By Garry Speight

Originally published in Australian Gliding, January 1983

There are three new shapes of cross-country tasks that can make cross-country flying very much cheaper. I call them the Arrow, the Fox, and the Star.

Retrieve Costs

Cross-country gliding is not cheap. However, in one respect it is a great deal more expensive than it could be and that is in the matter of retrieves from outlandings.

On any cross-country flight the pilot lays himself open to the risk of an outlanding, with consequent costs in money, in time, and in forbearance on the part of his family or friends.

One cannot insure against this kind of risk, except by trying to build up whatever kind of credit is appropriate. Every year, there are probably several retrieves that are costly enough, in cash or in domestic harmony, to be called disasters!

As a pilot's skill improves, he will aim for cross-country achievements that are near the limit of his abilities. He will try for Silver Distance, Gold Distance, Diamond Goal and Diamond Distance, then try to break State speed and distance records, enter for the Decentralised Competitions, and regional and State competitions. All these activities carry the risk of crippling retrieve costs, especially those for the FAI badges.

It takes practice to acquire cross-country skills, but in the tasks that a pilot sets for himself he can reduce the risks of high retrieve costs to a very low value by sensible task setting. If enough people recognise the benefits of tasks that are planned to economise on retrieves, perhaps competition organisers and even the FAI can be persuaded to adopt the same idea.

The essence of the tasks that I propose is to minimise the average distance from the home airfield. Since I don't think anyone likes going over and over the same short course, this means setting a number of turning points, and wrapping the task around the airfield.

In this way the average distance to possible outlanding points can be drastically reduced without reducing the length of the course which should, as usual, be set to make maximum use of the daylight and the weather.

I have experimented with setting up various kinds of closed-course tasks. Three that are very practical I call the Arrow, the Fox and the Star (Fig. 1).

Outlanding distance

Table 1 compares 300 km tasks of various kinds that can be flown from the Greenethorpe Gliding Club's field. I measured the mean distance of the turning points from the home field for each task as a rough indication of the maximum distance for retrieving in the event of an outlanding.

To make the comparison valid in spite of different task distances, I divided the mean distance to turning points by the task distance to give a percentage ratio. This was then divided by the ratio for the FAI triangle to show how each kind of task compares with an FAI triangle.

The table shows that an Arrow task has only 60% of the retrieve distance that an FAI triangle does, while the Fox task has 45% and the Star task 36%.

The average distance for possible outlandings will be somewhat less than the maximum. It is more difficult to calculate but, for these tasks, is in roughly the same proportions as the maximum distance.

Fig. 2 shows maps of some of the tasks of Table 1, drawn to scale. One can clearly see that the average distance from the home field of all the points on the FAI triangle is more than 50 km, whereas those on the Arrow task average about 30 km.

Cheaper Cross Countries

If we estimate that the costs of retrieving are proportional to the distance, we can say that., if a pilot paid $200 for retrieves in a competition using FAI triangles, he would have been saved from $80 to $130 by the setting of Arrow, Fox or Star Tasks of the same length.

Factors to consider

The factors to consider in planning a cross-country task of a certain total distance can be grouped under the headings of expense, challenge, and danger.

Expense

i. The ratio of average outlanding retrieve distance to total distance should be as small as possible.

ii. All turning points should be rounded in the same direction, to make use of a camera mounted on only one side of the sailplane.

Challenge

i. No leg of the task should have to be flown twice.

ii. Each leg should be long enough to test the pilot's skill in navigation, and the intermediate legs should not pass so close to the home field that they are just like outbound or inbound legs.

Danger

i. Tracks to and from a turning point should not be in the same line, or at such an acute angle that there is danger of head-on collisions.

ii. Turning points, where aircraft congregate and the pilots are very busy, should not be too numerous.

iii. Intersecting tracks should be avoided.

Features of various tasks

No turning points

Straight distance flights or goal flights are preposterously expensive for retrieves. They are practical only for soaring safaris.

One turning point

Dog-leg tasks are only slightly less expensive than straight distance tasks. Out-and-return tasks are still extremely expensive, and are very dangerous for head-on collisions, as well as being boring.

Two turning points

All triangle tasks are expensive, but long triangles are more expensive than FAI triangles, whereas flat triangles are cheaper. Hazards arise if any of the angles become too acute. An extremely flat triangle is like two consecutive out-and- return tasks: cheaper, but just as dull and dangerous.

Three turning points

Various task shapes can be made using three turning points, but the cheapest and most useful is the arrow task, with the turning points roughly equally spaced on a circle around the home field. This arrangement wraps the task around the field and ensures that, none of the angles is too acute for safety.

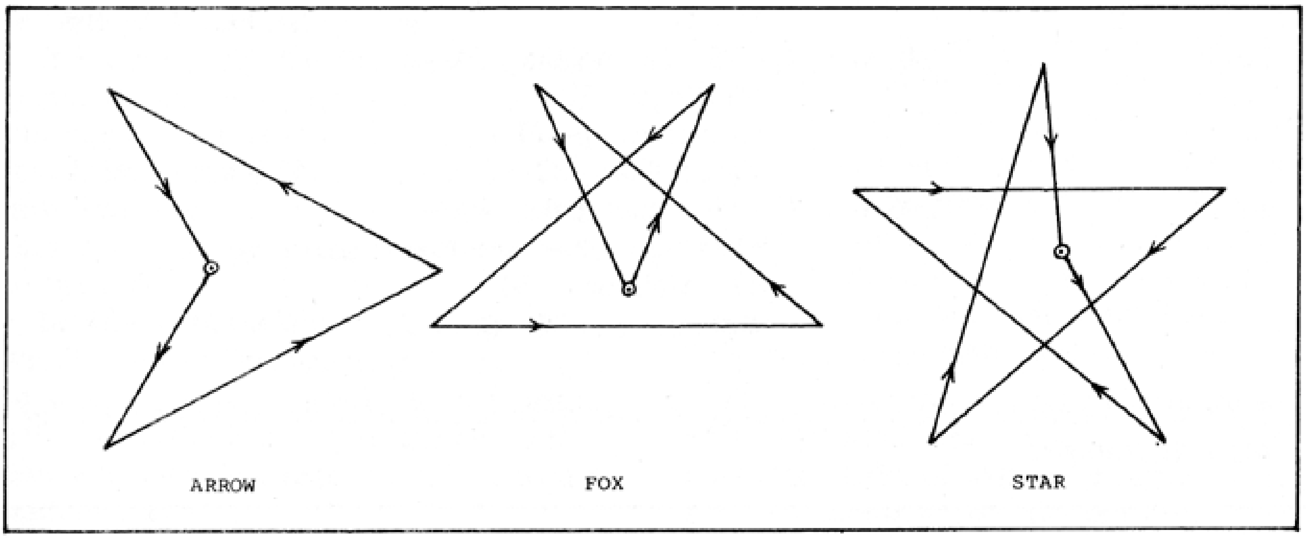

Fig 1. Arrow, Fox and Star tasks.

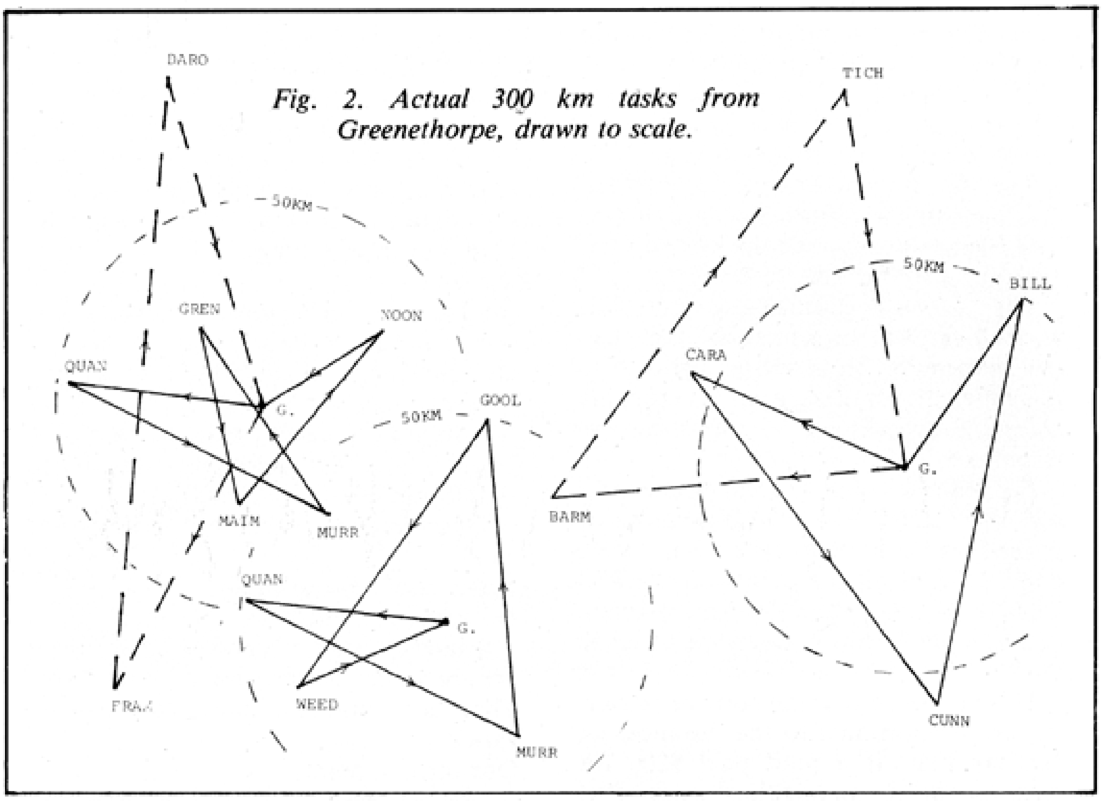

Fig. 2. Actual 300 km tasks from Greenethorpe, drawn to scale.

TABLE 1. COMPARISON OF ACTUAL 300 KM TASKS FROM GREENETHORPE

Task Type	Total Distance	Task Legs and Turning Points	Mean T.P. Kilometres	Distance Ratio*
Goal	315 km	G—315—Tocumwal	315 km	336%
Out and Return	308 km	G—154—Moombooldool —154—G	154 km	168%
Long Triangle	303 km	G—145—Kamarah—83— Combaning—75—G	110 km	122%
FAI Triangle	304 km	G—87—Barmedman—123— Tichborne—94—G	90.5 km	100%
Flat Triangle	319 km	G—81—Frampton—153— Daroobalgie—85—G	83.0 km	87%
Double O & R	306 km	G—90—Bethungra—153— Canowindra—63—G	76.5 km	84%
Arrow	309 km	G—59—Caragabal—101— Cunningar—99—Billimari— 50—G	55.0 km	60%
Fox	318 km	G—49—Quandialla—74— Murringo—77— Gooloogong—79— Weedallion—39—G	42.8 km	45%
Star	309 km	G—49—Quandialla—74— Murringo—56—Grenfell— 42—Maimuru—54— Noonbinna—34—G	32.6 km	36%

** Ratio of mean turning point distance to total distance, divided by the same ratio for the FAI triangle.*

For the best angles the second turning point should actually be somewhat further out than the other two. This task can provide a way of using a turning point that lies in good country beyond a patch of tiger country.

Four turning points

Since there are dangers in having too many turning points, it is worthwhile to consider only those four-point tasks that are cheap and have advantages in most other ways.

The fox task seems to be the best, its only disadvantage being that the fourth leg intersects the first and second legs, and the fifth leg intersects the second. This is not a great hazard because, even in a big field of gliders, very few aircraft will be two or three legs behind the leaders, and the areas of possible conflict will in any case be clearly shown on each pilot's map.

Five turning points

A satisfactory and very cheap task results from selecting five turning points roughly equally spaced on a circle about the home field and joining every second point to form a star. A leg passing close to the home field is then broken to form the first and last legs.

This task, by its extreme cheapness, is especially useful for a single glider, but may be somewhat hazardous for large fields of gliders at competitions. The boring five-point alternative is to fly twice around the one triangle.

The use of cheaper tasks

The use of the arrow, fox and star tasks in cross country practice flying allows a pilot to cover many kilometres without facing crippling retrieve costs or problems in finding the necessary crew.

It is not simply that the retrieves, when required, are quick and easy but also that one can make a habit of setting ambitious tasks, and simply cutting them short at any time when the weather turns bad or time runs out, by a small diversion back to the field.

In competitions and regattas there would not only be a substantial saving in cash for those pilots who don't manage to get around the course, but the chaos that one sees when the task is over-set would seldom occur.

With shorter retrieve distances many more out-landed gliders could be retrieved safely before dark. A significant number of contestants would also choose to land back on the field, knowing that the points penalty would be quite small.

The status of the arrow, fox, and star tasks relative to FAI requirements for badges and records is not clear. The rules in the Sporting Code seem to have deficiencies.

The badge requirements in Chapter 5 specify distance flights for all badges: 50 km, 300 km, 500 km, and 1000 km for Silver, Gold, Diamond and 1000 km badges respectively. A distance flight is defined in section 1,3.2 as "a flight measured for the distance between either the take-off place or a departure point and a finish point".

This definition does not appear to permit the use of any turning points at all on badge qualifying flights. However, the use of some unspecified number of turning points is acknowledged by Section 1.7.7: "The Distance Flown : The length of the arc of the great circle at sea level joining the departure point and the finish point or, if there are turn points, the sum of the great circle arcs at sea level for each leg of the course".

Assuming that Section 1.7.7 does modify the meaning of "distance flight" defined in Section 1.3.2, the fox, arrow, and star tasks (including stars with more than 5 points) should qualify as distance flights for the badges.

Total confusion is then introduced by Section 5.25 which presents "Badge Flight Requirements" in diagrammatic form, arbitrarily restricting the distance flight options to straight, zig-zag, triangle and out-and-return (with straight distance the only option for the Silver badge).

I cannot see that there is any logic in these restrictions. A thousand kilometres is a thousand kilometres, whether by way of two turning points or seven.

Cheaper Cross Countries

If it seems that the day might die when only 600 km has been covered, only the foolhardy would set out on a thousand kilometre triangle, whereas on the star task one could probably land back, if necessary, to try again next day.

The rules for the Australian decentralised competitions specify only tasks that have high risks of expensive retrieves. I, for one, cannot afford to compete.

Garry in a glider lent to him by Justin Wills and Brad Edwards. In 1998, he flew it to 23,000 feet at Omarama, NZ, to complete the FAI Diamond C badge, No. 6287.

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.

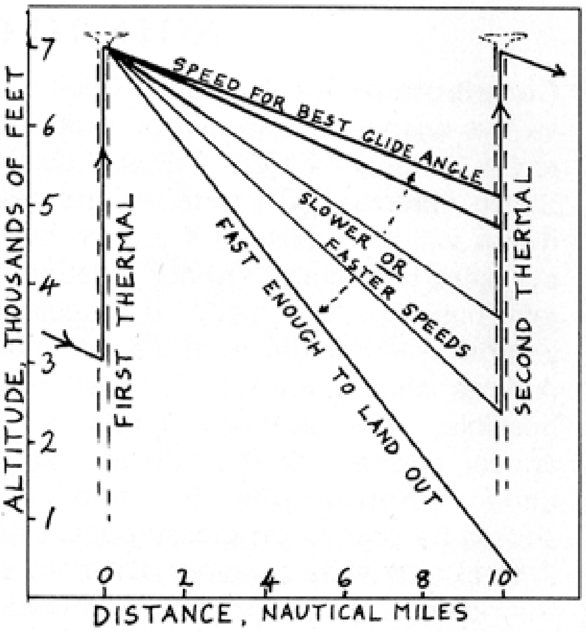

Fig 1. Altitude/Distance diagram for thermal cross-country soaring

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).

The Thermal Interception Diagram

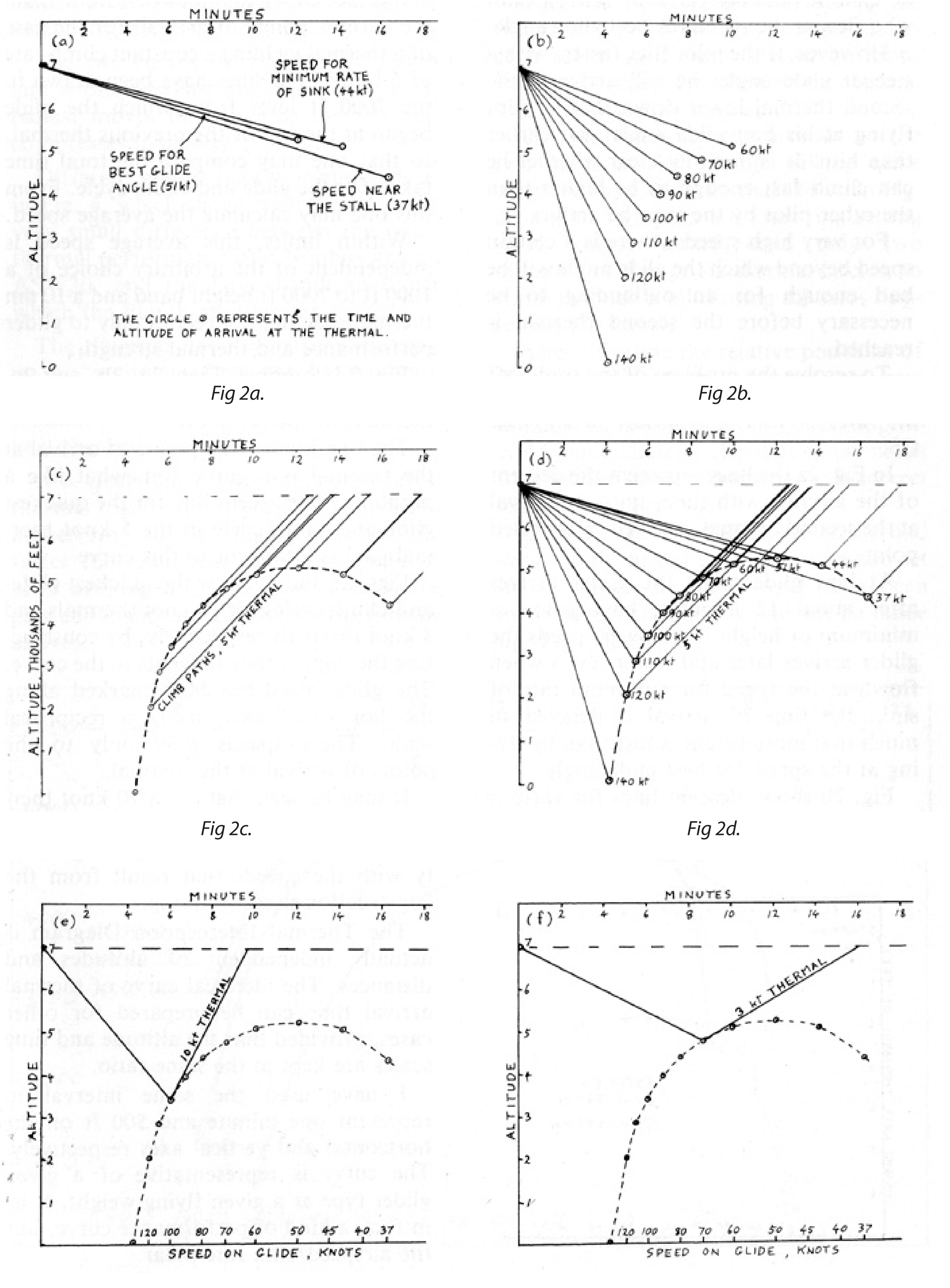

Fig 2a.

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

The Thermal Interception Diagram

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-

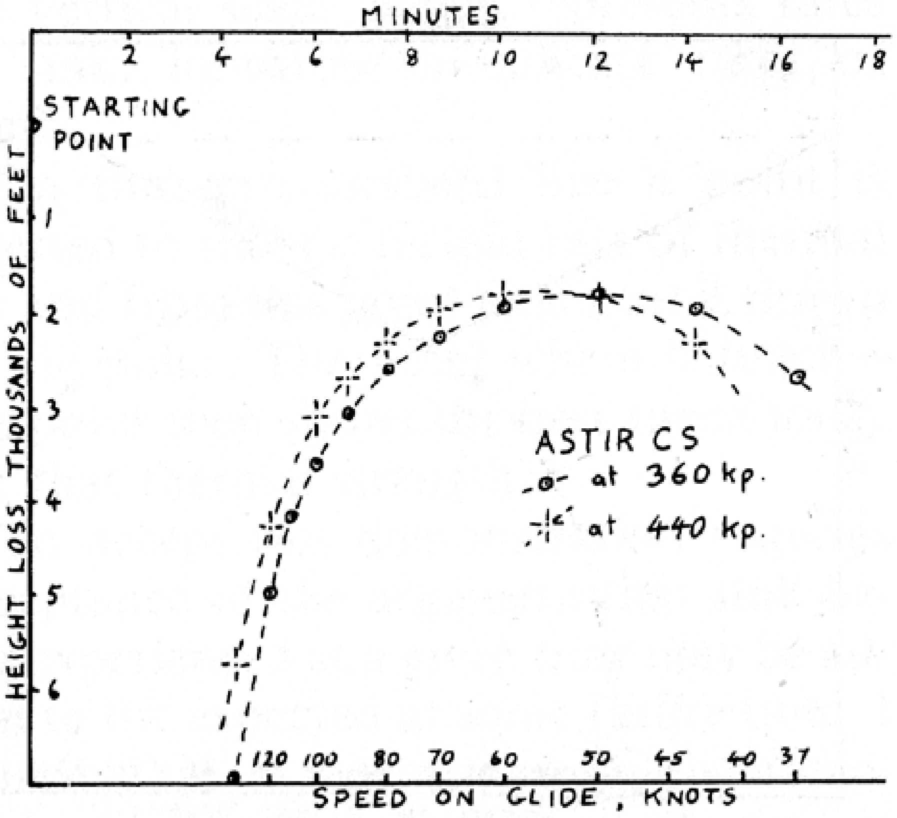

Fig 3. Thermal Interception Diagram for the Astir CS in the 10-mile case, showing the effect of water-ballast

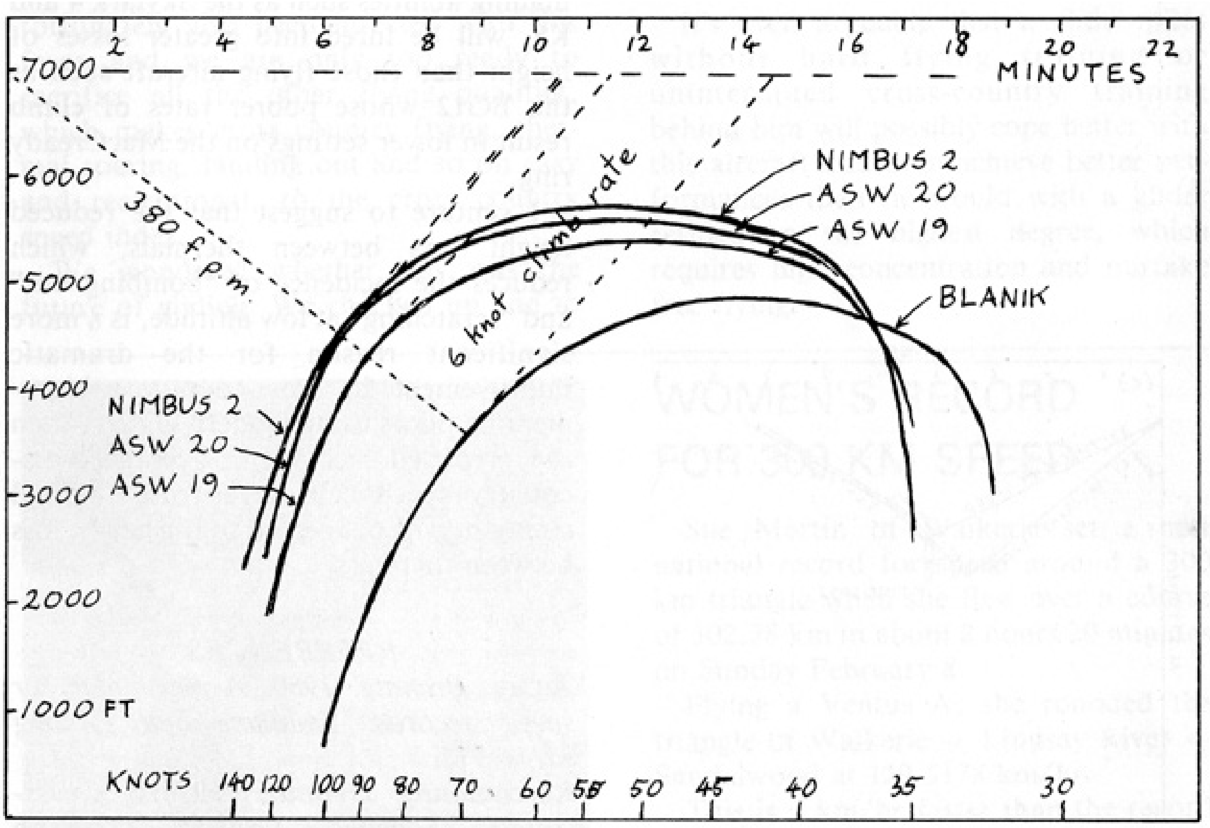

Fig 4. Comparison of the performance of several types of glider using the Thermal Interception Diagram

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

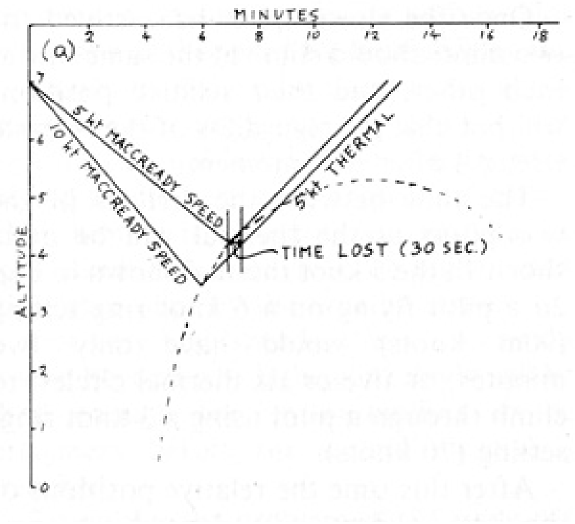

Fig 5a.

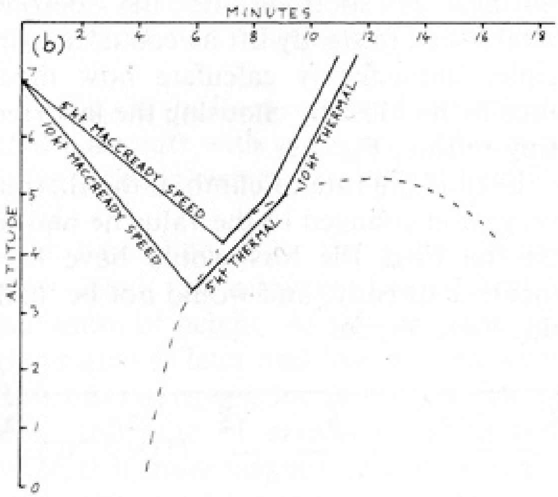

Fig 5b.

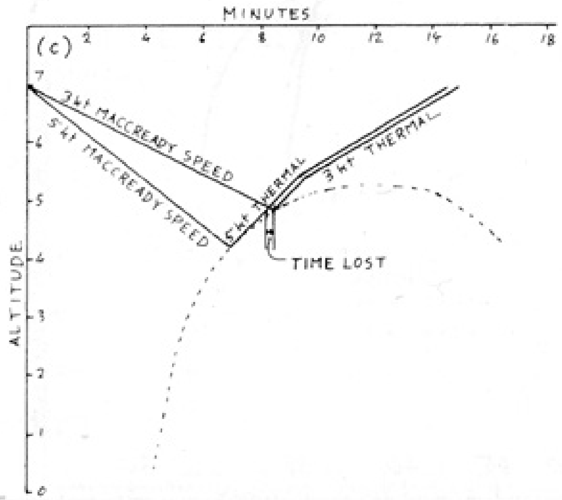

Fig 5c.

Fig 5. Time lost by incorrect assessment of the initial climb rate

The Thermal Interception Diagram

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.

References:

- Edwards, A., 1964. “The Arm-chair Pilot”, Sailplane and Gliding, October 1964, p364
- Reichmann, Helmut, 1978. “Cross-country Soaring”, Graham Thomson Ltd., U.S.A. (English language edition).
- Welch, A., Welch, L., and Irving, F., 1968. “New Soaring Pilot”, John Murray, London, 305 pp.

Rate of Climb in Thermals

By Garry Speight

As background to discussing the use of water ballast (the next article) I had to explain details of glider performance at circling speed, the likely lift profile of thermals, and the resulting rate of climb.

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The rate of climb in thermals is one of the most important things to consider when comparing one type of glider with another, as when thinking of buying a new glider, or when choosing one to fly in competition.

Recently, with most gliders having provision, through the use of water ballast, for reducing the wing loading in flight, every competition pilot has a daily need for some information on the relative climbing performance of his glider with and without water ballast.

The published performance polar curve of a sailplane does not yield thermalling performance directly, but it provides the basis for computation of the glider's sink rate in circling flight at various speeds (see Welch et. al., 1968, p. 138-142): I have constructed the nomogram shown in Figure 2 to simplify this task. Most of the rest of the paper is an attempt to construct simple but plausible models of thermals, so that the known rates of sink of circling gliders can be converted to estimates of the rates of climb that can be achieved in the sorts of thermals that they are likely to be flown in. Only then can a pilot get something approaching an objective estimate of relative thermalling performance.

Circling Performance

The basis for estimating the still-air circling performance of a glider is the low- speed end of its performance polar curve, the part within about 10 knots of the stalling speed. Good data for this

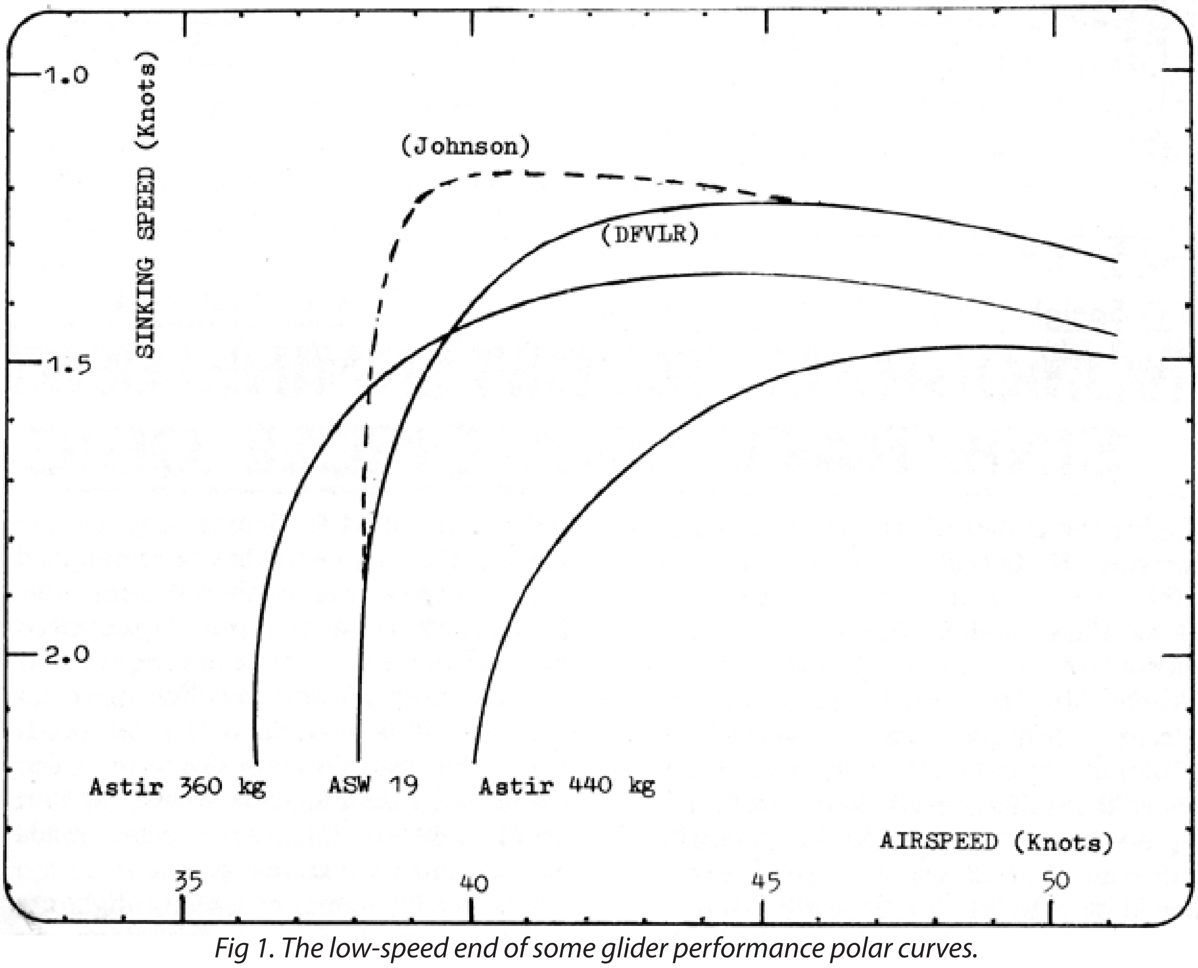

Fig 1. The low-speed end of some glider performance polar curves.

part of the curve is so difficult and costly to obtain that one should be a little sceptical of the curves published by manufacturers and even those of independent testing authorities. Particular note should be taken of the weight of the glider as tested. The performance curve at any other weight must be estimated by multiplying both the airspeeds and the corresponding sinking speeds by the square root of the ratio of the actual weight to the test weight. The two weights of most interest to a contest pilot are the minimum weight that he can actually achieve with complete contest equipment, and the maximum permitted weight with water ballast.

In Fig. 1 I show relevant parts of the polars of an Astir CS at 360 kg weight (Light) and at 440 kg (Heavy) attained by carrying 80 kg of water ballast. The curves are based on test data in "Australian Gliding (Anon. 1979). Also shown are two curves for the ASW 19 (Anon. 1978), which, according to Richard Johnson, has a speed for minimum rate-of-sink only two knots above the stalling speed. Very careful flying and smooth air are required to maintain control at such a slow speed, and it would perhaps be more realistic to aim to hold a steady speed four knots above the stall. The DFVLR figures may be the more useful. The Astir has been designed specifically to have gentle stall behaviour (Eppler, 1977) which results in the speed for minimum sink rate being eight knots to nine knots above the stalling speed. In this case it is feasible to fly at speeds below that for minimum sink rate, which could be an advantage in circling flight at small radii of turn, so I have made calculations for various speeds.

The aerodynamics of circling flight are well known, but the calculations are tedious. To help pilots to work out the behaviour of their sailplanes I have prepared the nomogram in Fig. 2.

The performance data required are (i) an airspeed value from the polar curve, selected as being a useful basis for calculation, either the speed for minimum rate of sink, or some arbitrary margin above stalling speed, e.g. two knots or eight knots above the stall (N.B. only the first option is mentioned in the titles on the nomogram); (ii) the rate of sink at the selected airspeed, read from the polar curve. Values of (i) and (ii) are represented on the nomogram by sets of curves on the left and right respectively. For each pair of values (i) and (ii), the nomogram is used to obtain a number of values of the rate of sink, angle of bank and actual airspeed, corresponding to a number of selected values for the radius of turn. To use the nomogram, enter it at the top margin at a selected radius of turn. Bring a line down vertically to meet the chosen straight-flight airspeed curve. At this point the actual airspeed required in the turn may be interpolated between the dashed lines, and the required angle of bank may be read on the vertical axis. Then carry the line horizontally to meet the appropriate curve for rate of sink in straight flight, then take it vertically down to the lower margin to read off the rate of sink in circling flight for the selected radius of turn.

Using the nomogram, one or more curves can be constructed, as in Fig. 3, showing rate of sink versus radius of turn. On the figure, curves are drawn for the Astir CS at straight-flight airspeeds that are eight knots, four knots and two knots above the stalling speed in both ballasted and unballasted conditions. For the unballasted glider, it may be seen that, at all radii less than 340 ft, the four knots- above-the-stail speed yields smaller rates of sink than the speed for minimum sink, eight knots above the stall. At two knots above the stall, sink rates are greater again except at very small radii, where adequate speed control would not be possible, so four knots above the stall appears to be a good speed for thermalling. With ballast the curves are steeper, the performance falling off at larger turn radii than in the unballasted state.

Since, in general terms, lift is strongest in the centre of a thermal, good thermalling performance depends on curves that are as high up and as far to the left as possible on this Figure. It is a definite disadvantage to carry water ballast or to have a high stalling speed, whether it is due to a high wing loading or to aerodynamic inefficiency. It is not possible, however, to estimate the **amount** of disadvantage without information about the distribution of lift in thermals.

Rate of Climb in Thermals

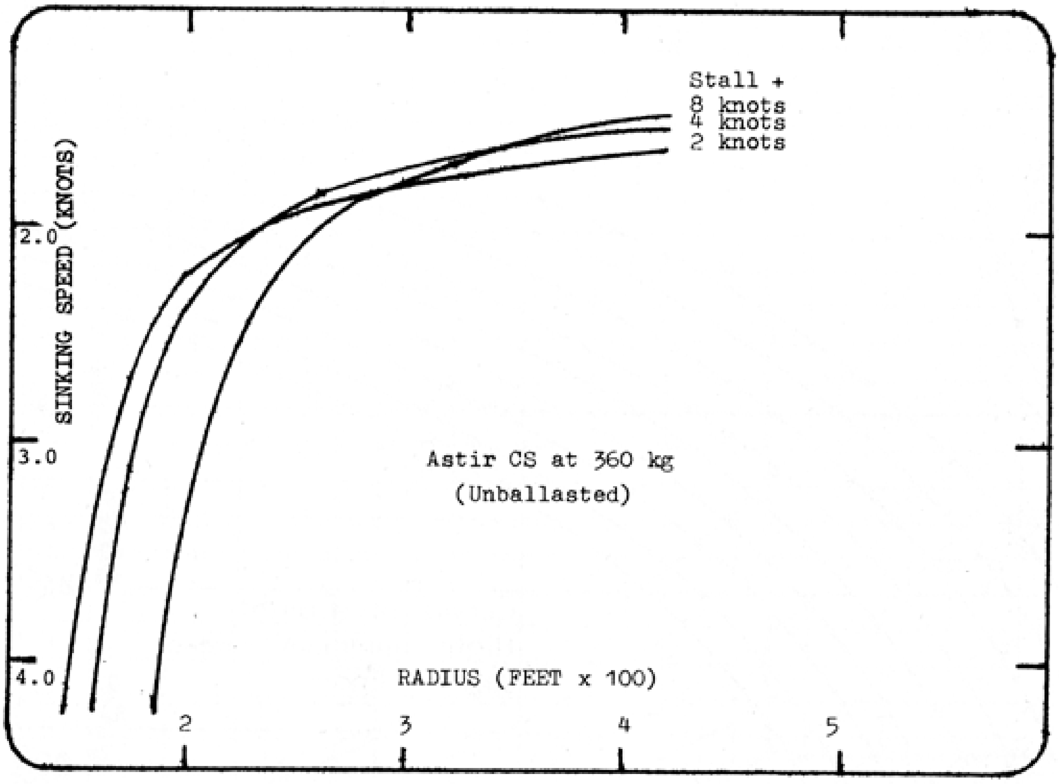

Fig 3a.

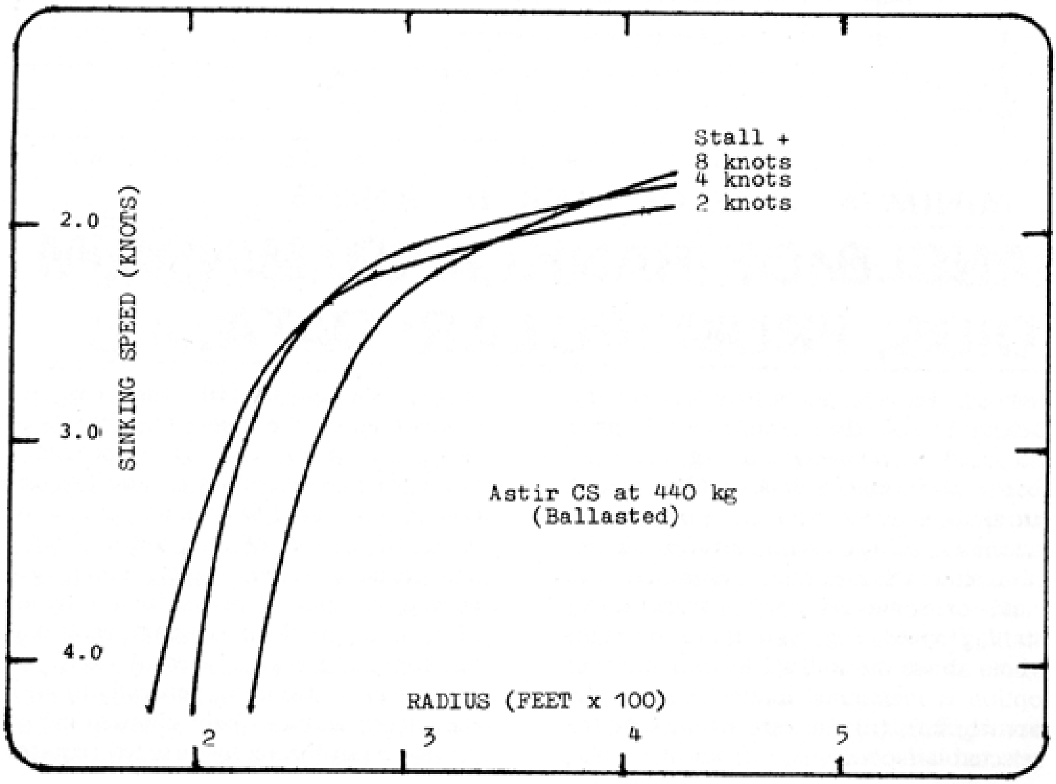

Fig 3b.

Fig 3. Turning rate of sink of the Astir CS plotted against radius of turn for airspeeds 2 knots, 4 knots, and 8 knots above stalling speed in the turn. (a) unballasted (360kg), (b) ballasted (440 kg).

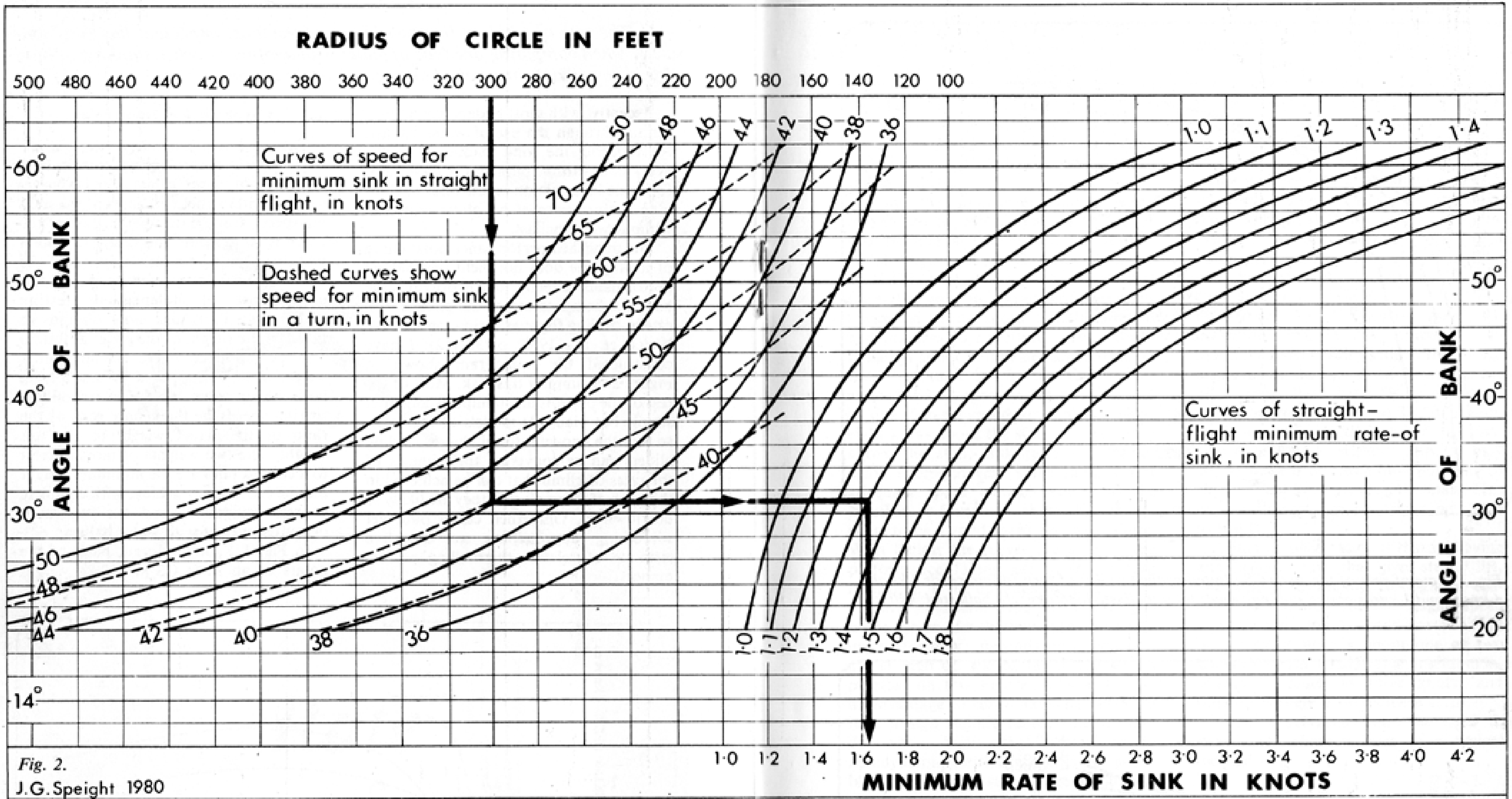

Fig. 2.
J.G.Speight 1980

NOMOGRAM TO DETERMINE BEST SPEED, ANGLE OF BANK AND MINIMUM SINK RATE IN A CIRCLE OF GIVEN RADIUS, FROM POLAR DATA.

Models of Thermal Lift Distribution

Thermals may be regular or irregular, but there is little point in trying to analyse irregular thermals. Barry Wrenford has jokingly classified them into various types (Wrenford, 1969). I will consider only the regular ones, and presume that irregular ones are much the same on the average, just more difficult to work. The general model I will discuss is an isolated circular patch of lift, strongest in the middle, with lift decreasing equally in all directions away from the central axis. Whether it is a vortex ring, a bubble or a column is not relevant, so long as the lift does not change too rapidly with height in the part of the thermal we are thinking about.

Even such a simple, regular kind of thermal may vary in different ways: in strength, in width, and in the way in which the lift decreases away from the centre.

We have certain clues about thermals from what happens when we try to fly them. Dupont (1974) quotes a survey by Gerhard Waibel indicating that most competition pilots in their efforts to maximise rate-of-climb use between 35° and 45° of bank. Referring to the nomogram. Fig. 2, since the speeds for minimum sink rate of practically all modern gliders fall within the range displayed on the figure, it follows that the pilots must have been flying circles of radius between 150 ft. and 360 ft. Again, from my experience, I would say that circling a Blanik, without flap, at only 20° of bank produces a miserable rate of climb except in very strong thermals. This implies a thermal radius of around 500 ft. to 600 ft.

A further observation is that if, having established a turn that gives steady lift, one happens to blunder through the centre of the thermal without changing speed or bank angle much, the increased lift at the centre is usually about one or two knots above the steady value: it seldom increases as much as three knots, and sometimes there is no increase at all.

These observations may be used to specify the characteristics of a typical thermal:

(i) somewhere in the range from 150 ft. to 360 ft. radius the lift decreases with increasing radius at about the same rate that the glider sinking speed decreases with increasing radius, so that the radius of turn has rather a small effect on rate of climb within these limits

(ii) Beyond 360 ft. radius the lift falls off rapidly until it is practically zero at about 500 ft. or 600 ft.

(iii) Between a useful circling radius and the centre the lift increases by one or two knots.

A number of theoretical models of the size and shape of the zone of lift in a thermal have been constructed over the years. They are illustrated in Figs. 4 and 5. In these and the following figures I have adopted a convention to simplify all comparisons: the centre of the thermal is on the left, and the vertical axis reads downwards, as on a performance polar, showing the decrement of lift relative to the upward velocity of the air in the centre of the thermal called the central velocity. The graphs show how much slower the air at some radius is going up. Later figures also show how much slower than that the glider is going up. If a particular thermal has a central velocity of, say, six knots we can represent the surrounding air by a horizontal line extending to the right at a lift decrement value of six knots.

Fig. 4a shows some British work. In 1967 the British Gliding Association adopted a datum thermal proposed by H.C.N. Goodhart for the purpose of handicapping gliders according to their predicted cross-country speeds in the prevailing weather. This datum thermal had specified strength, radius and lift distribution: a parabola. It fits quite well to all the criteria above, the only problem being how to generalise it for different thermal strengths: should one extend the same curve to make a stronger, wider thermal, or should one change the constant of the parabola to increase the strength without increasing the maximum radius? Later, (Strachan, 1974) the B.G.A. set up a new “1975” datum thermal, also shown on Fig. 4a, which seems far too forgiving! Although it yields climb rates of only two knots to two-and-a-half knots for most gliders, it has the very large radius of 1000 ft, and such a gentle rate of lift decrement with radius that changes in

Rate of Climb in Thermals

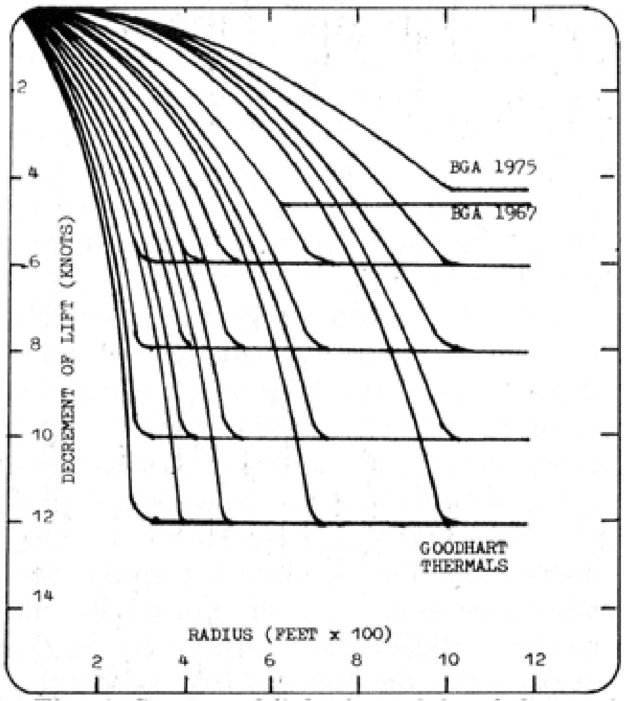

Fig 4. Published models of thermal lift distribution: (a) Goodhart; BGA.

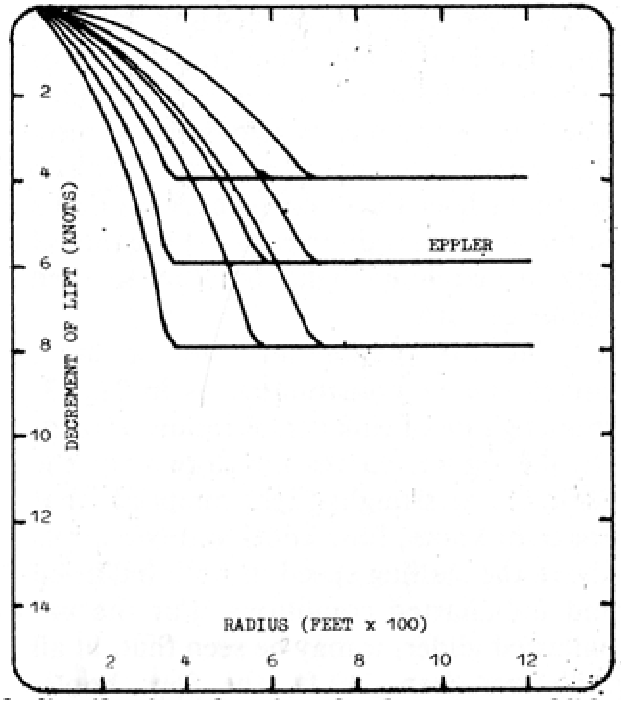

Fig 4. Published models of thermal lift distribution: (b) Eppler.

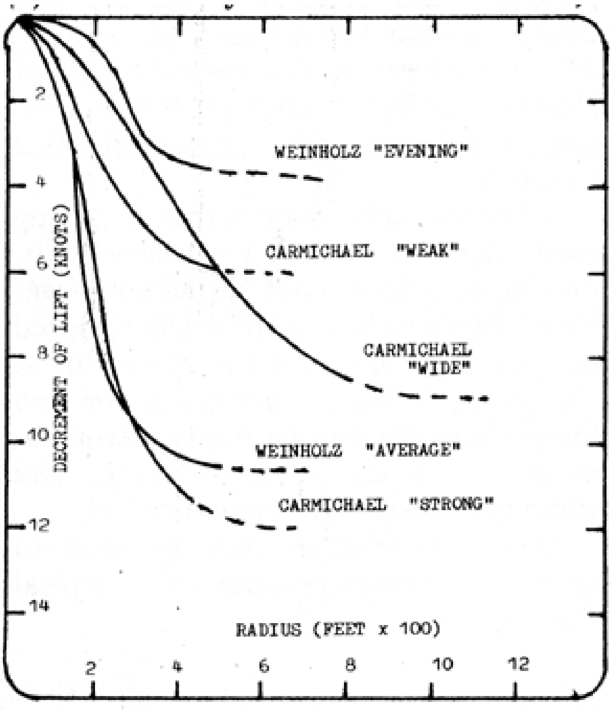

Fig 4. Published models of thermal lift distribution: (c) Carmichael (Reichmann, Holighaus, Weinholz)

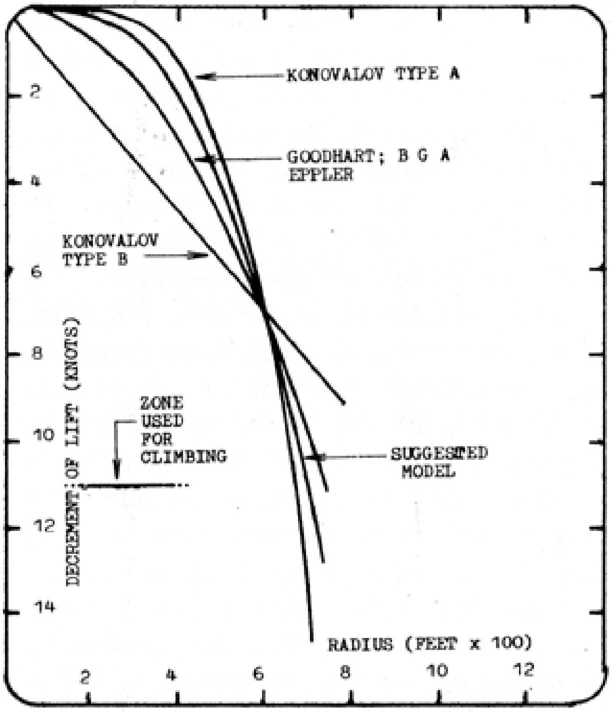

Fig 5. Thermal models with different profiles of lift distribution.

wing loading and angles of bank do not greatly affect the rate of climb. Subsequently, Goodhart produced a whole family of 25 parabolic lift distribution profiles as shown, which have since been used in papers by Frank Irving (1972) and Martin Simons (1976). Dr. Eppler (1977), discussing the Astir design concept, also used a family of parabolic thermals, nine in all, in the central part of the range used by Goodhart (Fig. 4b).

A different tradition of thermal modelling, shown in Fig. 4c, represented by Reichmann (1978), Weinholtz (1969) and Holighaus (1971) is based on a paper in "Soaring" by Carmichael (1954). These thermals, with the exception of the "wide" type which would be classed as "normal" by other authors, are very vicious indeed! In the supposedly typical “strong” thermal an unballasted standard class glider achieves maximum climb at about 50° of bank, and the climb rate will then be only four knots, whereas blunders into the core at the same bank angle will yield nine knots momentarily. A standard class glider carrying ballast will scarcely climb at all. Similarly the major part of the lift in the “weak” thermal can be reached only by extreme angles of bank and low wing loadings. On the basis of his model, Carmichael calculated that optimum aspect ratios would be about 10:1. The fact that such low aspect ratios have not been adopted since does not appear to have caused later authors to question his thermal models. Within the range of circling radius available to sailplanes the Carmichael “strong” and “weak” thermals display the “hyperbolic” lift distribution which, according to Barry Wrenford marks the dreaded “Cowra Corkscrew Thermal.” Such thermals no doubt exist but, fortunately, one is seldom forced to rely on them!

In the Soviet Union D.A. Konovalov (1970) (see Strachan, 1974 and Reichmann, 1978) collected data on a large number of thermals which indicated that, rather than a parabolic lift profile, with the decrement of lift proportional to the square of the radius, thermals have one of two types of lift profile (see Fig. 5): Type A has the decrement of lift proportional to the fourth power of the radius, and Type B has the decrement of lift directly proportional to the radius. The two types were both found to occur with a variety of thermal diameters and thermal strengths. In Fig. 5 I have plotted types of thermal model scaled so that each has a lift decrement of seven knots at 600 ft. radius. Konovalov types A and B are shown, as well as the parabolic type used by Goodhart and Eppler, and the type that I am putting forward.

In the absence of data to the contrary, I propose as a simplified model that “normal” thermals conform to a single equation of lift decrement versus radius, the stronger thermals having larger maximum radius, and the weaker thermals somewhat smaller maximum radius, simply as a consequence of the curve extending a greater or lesser distance before meeting the horizontal line where the lift decrement equals the central velocity of the thermal. This assumption simplifies estimation of glider performance because the best thermalling radius, angle of bank and speed to fly will not vary with thermal strength, and nor will the decrement of the gliders rate of climb compared with the central velocity of the thermal. That is, for a “normal” thermal the maximum climb rate of a given glider (identically loaded) will always be the same amount less than the upward speed of the air in the core of the thermal. For the application of this idea, the Konovalov Type B and the Goodhart and Eppler thermals have radii that vary too rapidly with thermal strength, while the Konovalov Type A not only varies rather too little in radius with different thermal strength, but also has a very small variation in strength across the core. After various trials with graph paper and performance curves, I propose a thermal model, as shown in Fig. 5., in which the decrement of lift varies with the cube of the radius. Specifically, for a “normal” thermal I propose the curve $y = 0.033 (x/100)^3$ where x is radius in feet and y is lift decrement in knots. This thermal matches the three “characteristics of a typical thermal” given earlier.

Such a normal thermal would be rather easy to work. Since quite a few thermals seem to be somewhat more difficult to work because they are not wide enough, I further propose a “narrow”

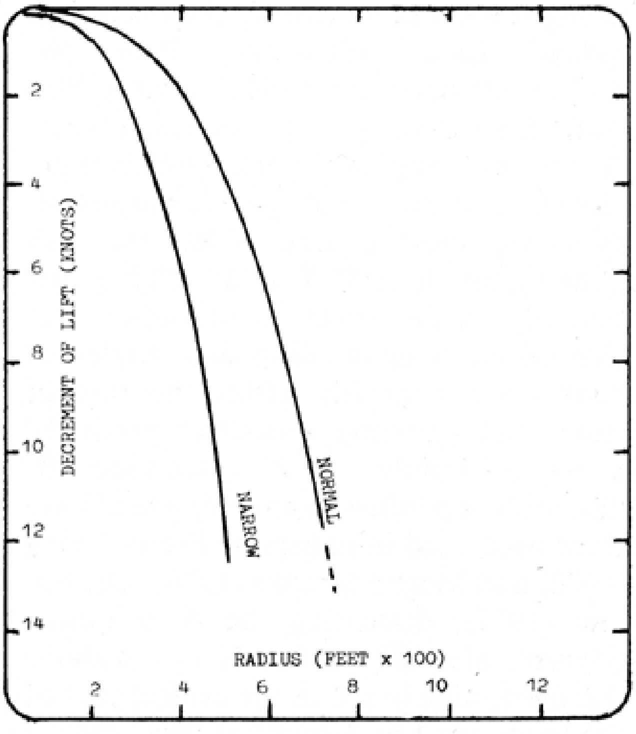

Fig. 6. Proposed “normal” and “narrow” thermals, $y = 0.033 (x/100)^3$ and $y = 0.10 (x/100)^3$ respectively

thermal, also with a cubic velocity distribution and the equation $y = 0.10 (x/100)^3$.

Profiles of these two types of thermal are plotted in Fig. 6, and their coordinates are listed in Table 1.

Rate of Climb in Thermals

Having settled on a pair of models of thermal lift distribution that will do for the time being, we can study, as an example, the relationship between circling performance of the Astir CS and the lift distribution in the model thermals, to discover the rates of climb, and best airspeeds, turn radii, and angles of bank for thermalling with and without water ballast, as predicted by the thermal models.

Figure 7 refers to the “normal” thermal. The lower curves show the rate of sink of the glider relative to the central velocity of the thermal. Climbing is possible whenever this rate of sink is less than the central velocity. The curves for the glider are plotted by simply dropping below the curve for the thermal itself, by the amount of sink shown in Fig. 3. Six curves are shown, for the ballasted and unballasted condition, and for airspeeds eight knots, four knots and two knots above stalling speed. Best rates of climb are obtained by an airspeed four knots above stalling speed, and selection of this speed also minimises the disadvantage of carrying water ballast when thermalling. Note that the curves are based on speeds selected from the polar curve for straight flight: the speed to fly actually increases with bank angle in each case, although it increases very little relative to stalling speed for the particular angle of Bank.

Figure 8 shows the glider’s thermal performance curves, for the “ + 4 knot” case with numerical values of speed and angles of bank taken directly from Figure 2. In this “normal” model thermal, the effect of ballasting the Astir CS from 360 kg to 440 kg is that the best thermalling speed rises from 44 knots to 50 knots, the best angle of bank goes from 35° to 38°, and the best rate-of-climb falls by 0.50 knots, the lift decrement increasing from 2.42 knots to 2.92 knots relative to the central velocity of the thermal.

In the case of the “narrow” model thermal, shown in Fig. 9, rates of climb are much

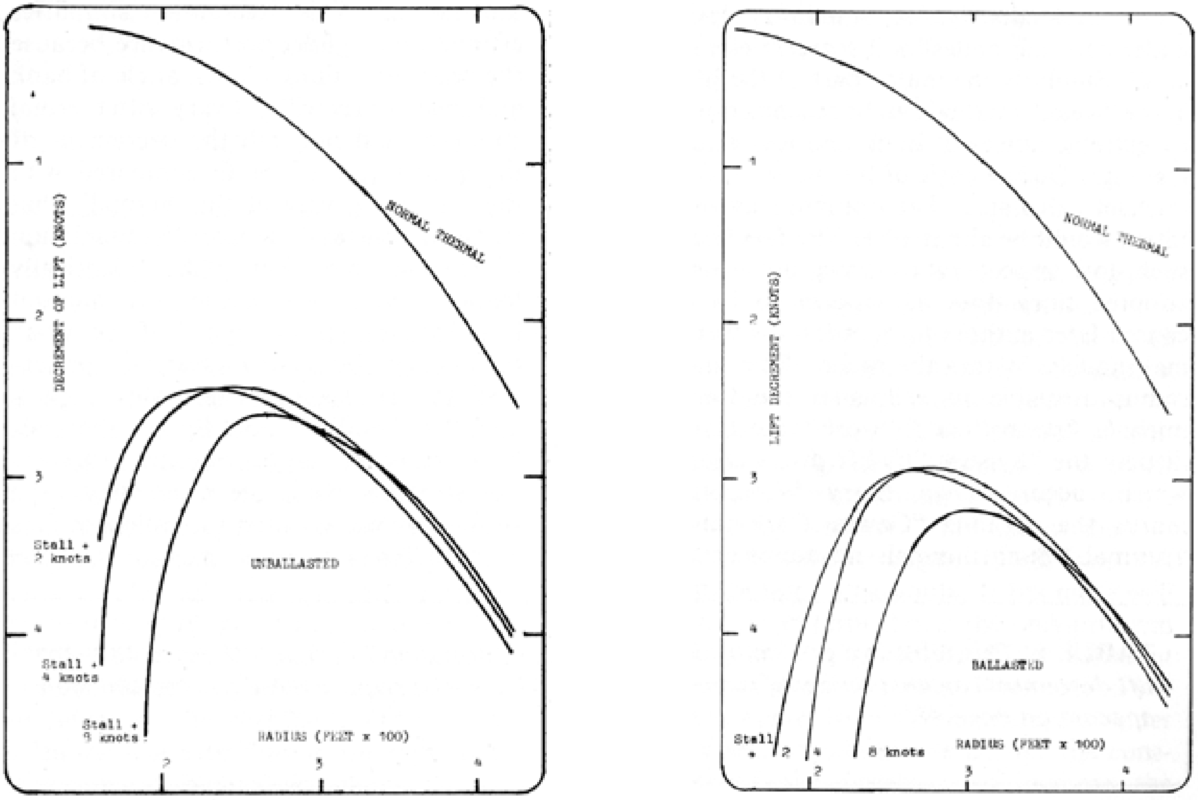

Fig 7. Rates of sink of the Astir CS relative to the central velocity of a “normal” thermal.

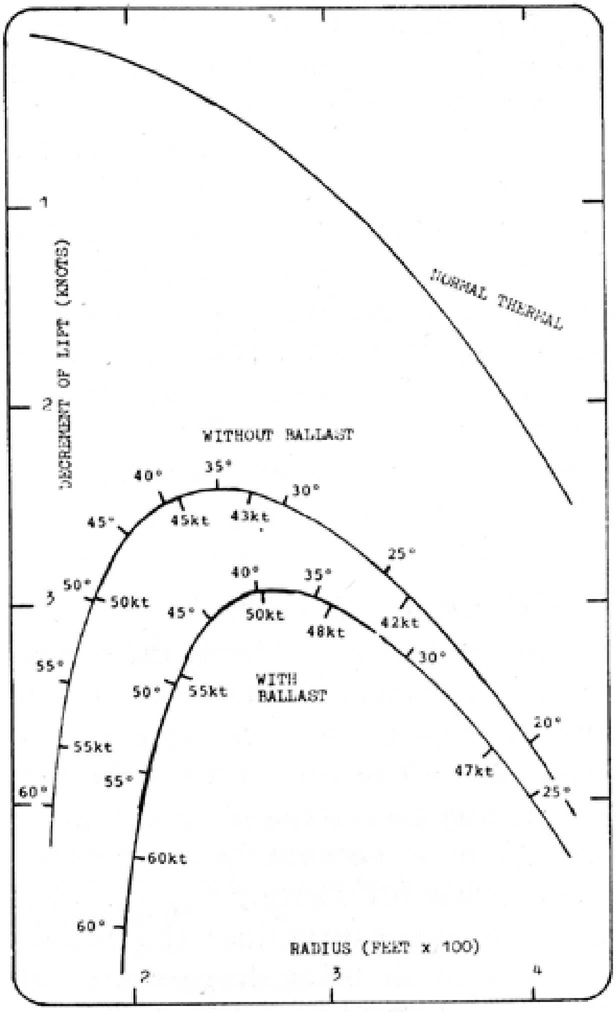

Fig 8. Speeds and angles of bank related to thermal performance of the Astir CS flown 4 knots above the stall in a "normal" thermal

reduced, and the disadvantage of carrying ballast is more pronounced because the practical circling radii are in the zone where the thermal lift is falling off rapidly with radius. Theoretically, maximum rate of climb will be achieved in the narrow thermal by flying within two knots of the stall, but the very narrowness of the thermal will make this impossible in practice because small piloting errors will result in very large fluctuations in thermal lift, that will certainly induce repeated stalls. Stalling in a thermal is foolish from every point of view: loss of height, loss of control, and possibly loss of life!

At four knots above the stall in a "narrow" thermal the minimum lift decrement without ballast is 3.14 knots, attained by flying at 47 knots with 42° of bank. With ballast, it is best to fly at 52 knots with 45° of bank, but this yields a lift decrement of 3.98 knots, a relative decrease in

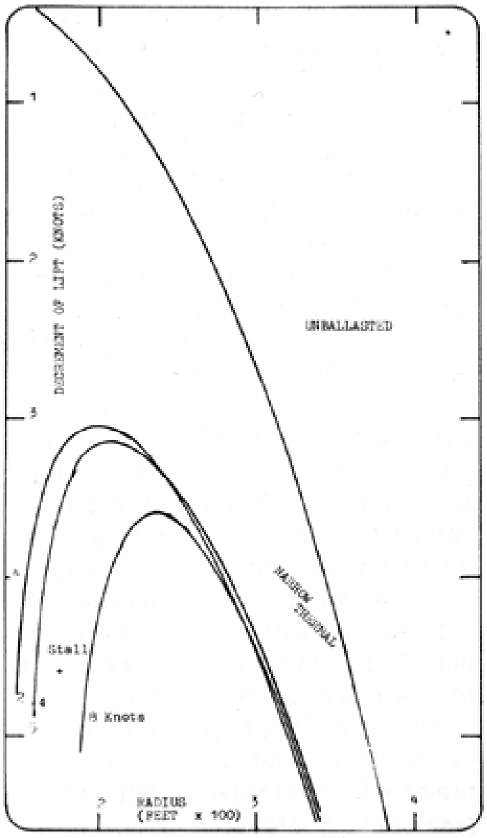

Fig 9a. Rates of sink of the Astir CS relative to the central velocity of a "narrow" thermal

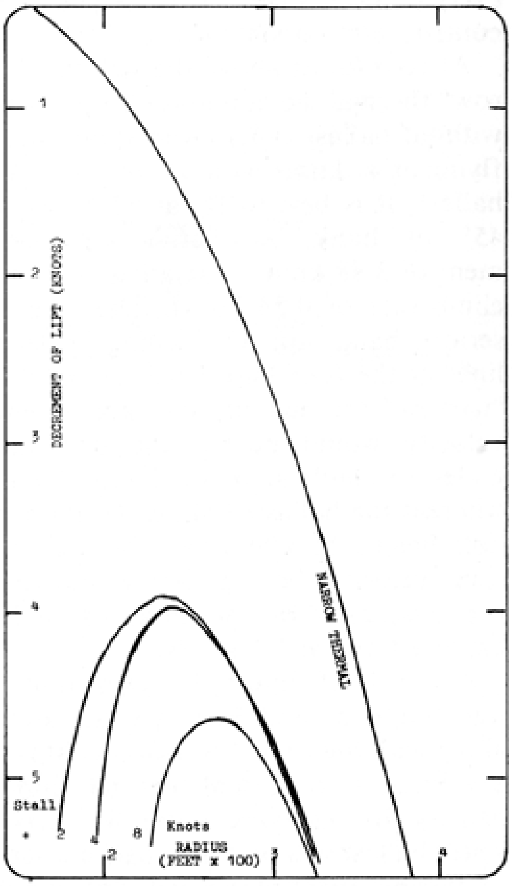

Fig 9b. Rates of sink of the Astir CS relative to the central velocity of a "narrow" thermal

climb rate of 0.84 knots. This is a very serious handicap: by drawing horizontal lines at the four knot level we see that a “narrow” thermal of four knots central velocity would permit the unballasted glider to climb at more than 0.8 knots, whereas the ballasted glider would barely hold height. In a “normal” thermal of the same velocity, both gliders would climb, the unballasted one at 1.6 knots, and the ballasted one at 1.1 knots.

As a rule-of-thumb, I suggest that current Standard and Racing Class gliders, along with the Astir CS, will sink at about 2.5 knots in a normal thermal, and the penalty for carrying some 80 litres of water ballast will be about half a knot. In a “narrow” thermal they will sink at about three knots, and the ballast penalty will be about one knot.

It should be possible to judge whether the thermal is normal or narrow by the amount of bank necessary to maximise the rate of climb (this idea comes from Herbert Pirker (1977)). When one is carrying ballast (and therefore still has the option of dumping it) a normal thermal requires less than 40° of bank; a narrow one requires about 45°. Judgement of these angles may be improved by marking them on the canopy. The decision to dump ballast depends on other factors beside the reduced rate of climb, but they will be discussed in another article.

More Realistic Thermals

To parry the charge of being excessively simplistic, I present the two sketches in Figure 10. Figure 10a is an impression of the complete lift profile of a simple thermal including the surrounding still air. I believe there is commonly a transition zone of gentle lift surrounding the thermal, out to two or three times the thermal radius, due to air being dragged up with the thermal. Any adjacent areas of heavy sink are, I think, usually localised in places where the thermal is tumbling due to wind shear.

I do not think that the circular-cubic model of about 400 to 700 ft radius is invalidated by the typical observation of much larger and less regular areas of lift in experimental traverses by instrumented aircraft, nor by the often puzzling behaviour of gaggles of gliders. It seems to me that larger thermals may have a compound structure, as is seen in actively- growing cumulus clouds. There may be a number of thermals rising as a cluster, Fig. 10b, with a particular individual thermal not necessarily remaining the strongest throughout the ascent. I suggest that each individual thermal of such a cluster often resembles one of the models that I am proposing, so that choice of wing loading and thermal technique remains related to the basic model. The effect of the other thermals in the cluster is to make it necessary to frequently explore the air around the thermal to find if a stronger one has developed adjacent to it.

Conclusion

I suggest that the simple models of “normal” and “narrow” thermals that I have described may be sufficiently realistic to provide the basis for estimating the comparative thermal performance of different gliders and for assessing the effect of water ballast on the rate of climb. The models could be validated, improved, or rejected by pilots willing to experiment in a systematic way, and to record their results. I would like to hear from any pilot who considers that the model should be changed in some specific way.

The table below gives coordinates for Fig. 6 on page 31

Rate of Climb in Thermals

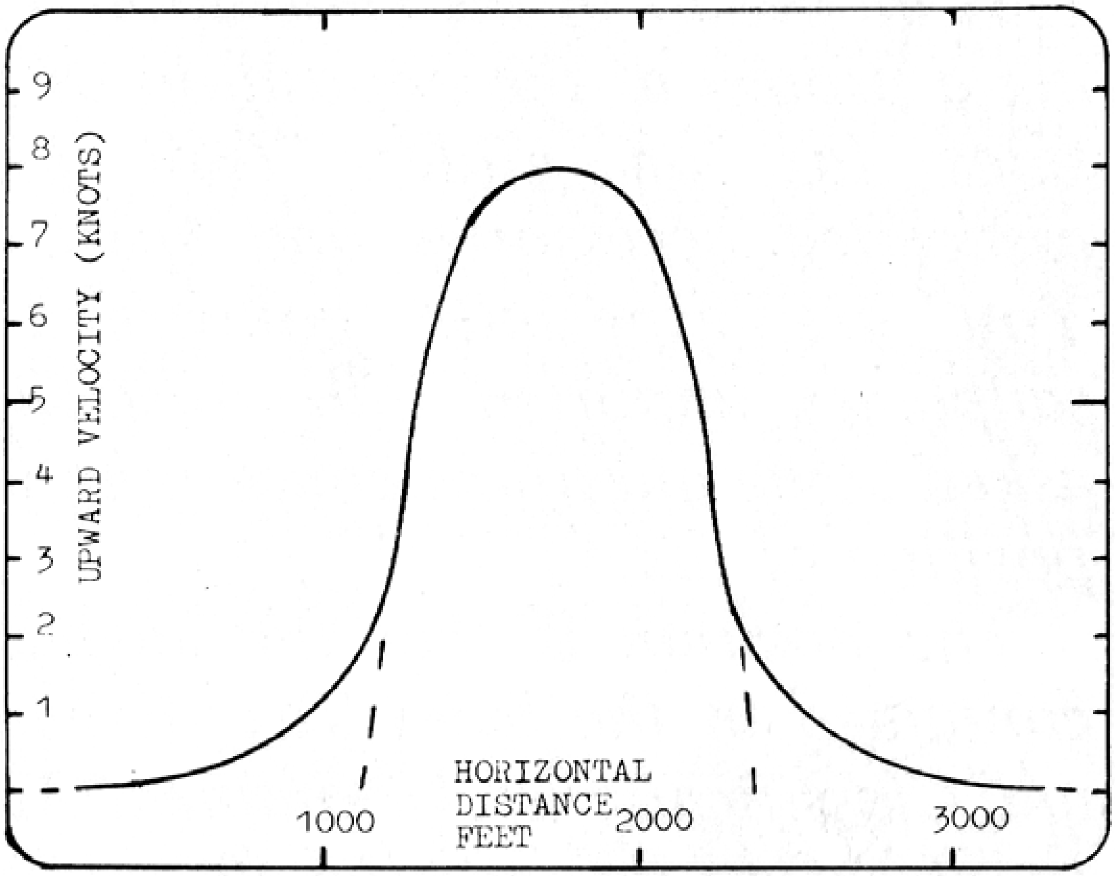

Fig 10a. Sketches of inferred thermal lift profiles: simple thermal

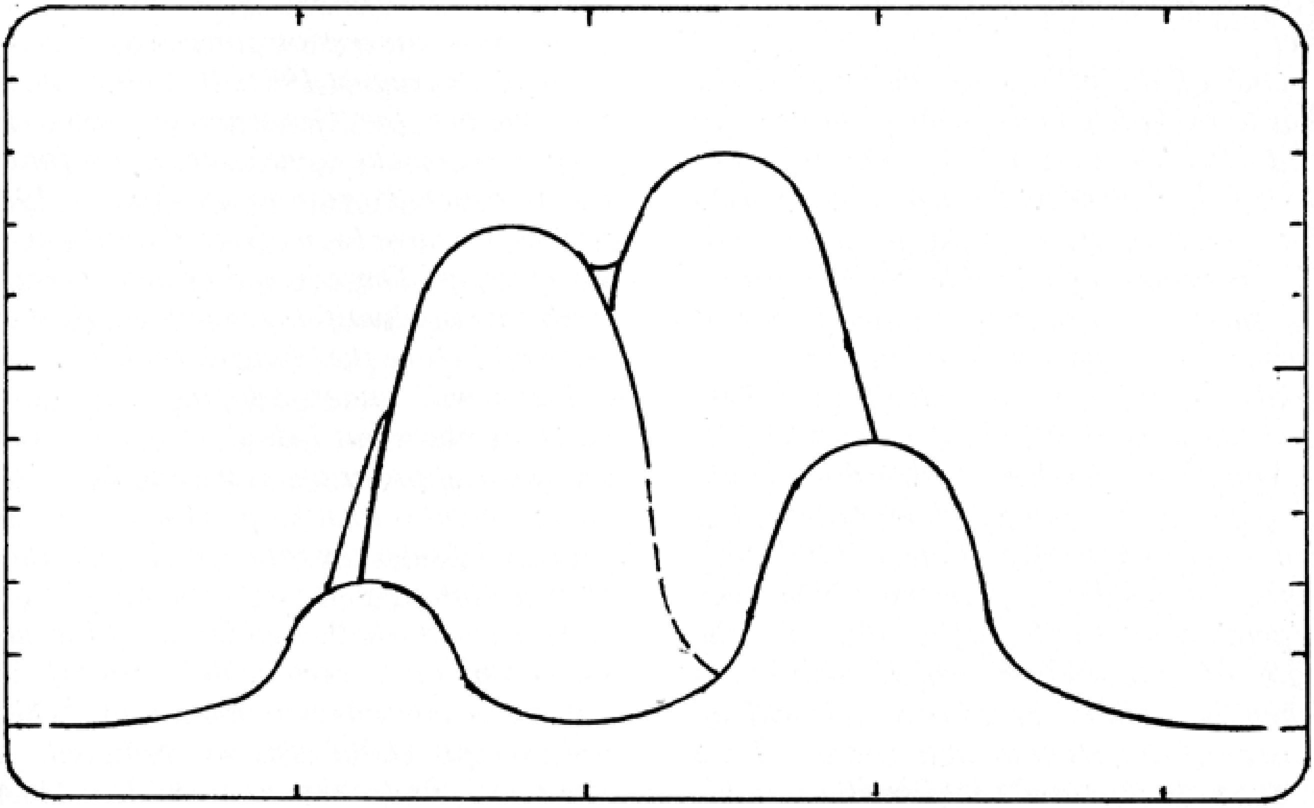

Fig 10b. Sketches of inferred thermal lift profiles: compound thermal

Rate of Climb in Thermals

Acknowledgement

Many thanks to Reg Munyard for drawing the nomogram and to Joe Borg for drawing the other figures.

Radius (feet)	Lift Decrement (knots)	
	Normal Thermal	Narrow Thermal
0	0.00	0.00
100	0.03	0.10
160	0.14	0.41
180	0.19	0.58
200	0.27	0.80
220	0.35	1.06
240	0.46	1.38
260	0.59	1.76
280	0.73	2.20
300	0.90	2.70
320	1.09	3.28
340	1.31	3.93
380	1.83	5.49
420	2.47	7.41
500	4.17	-
600	7.20	-

Table 1.

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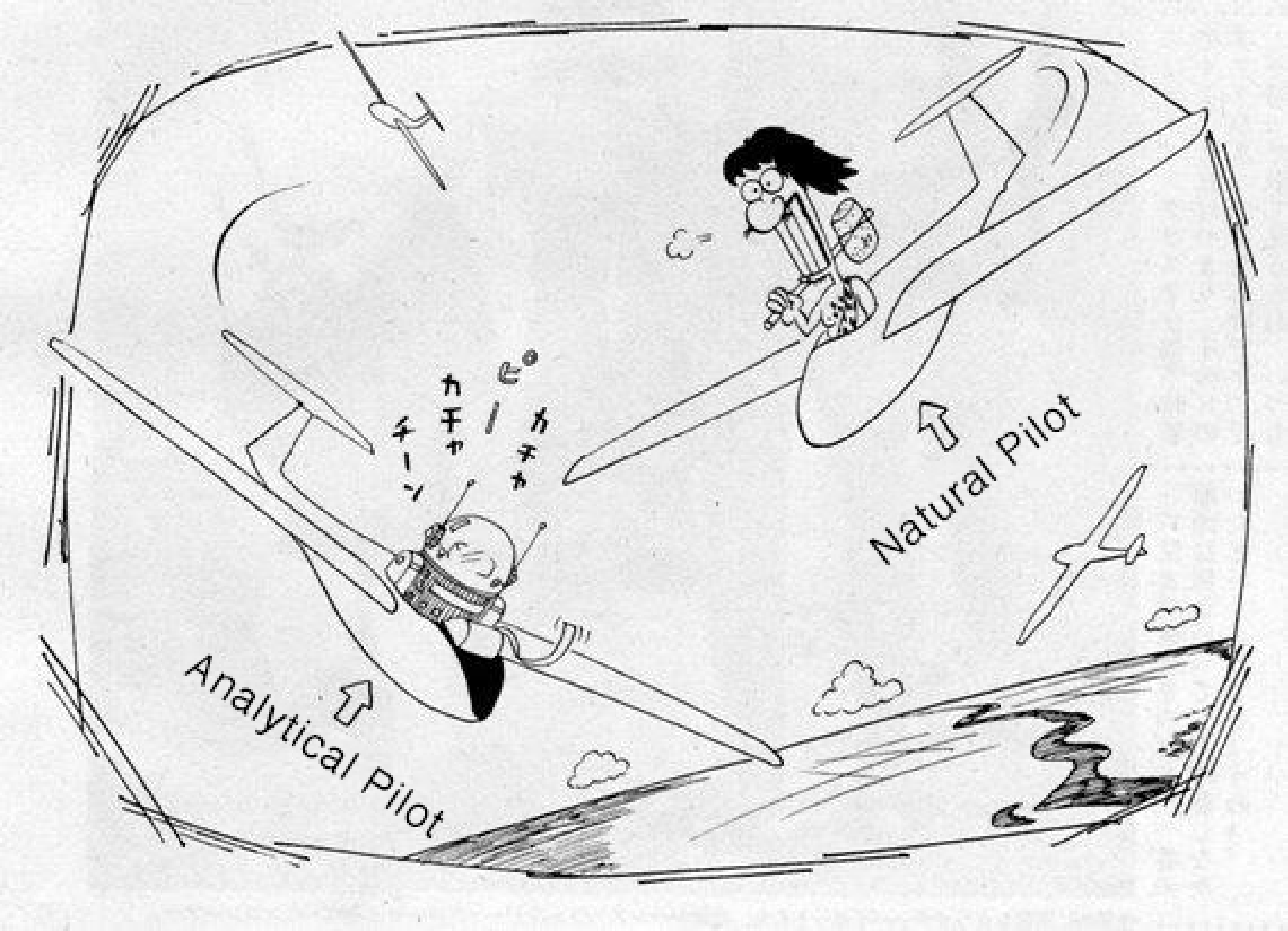
Rate of Climb in Thermals

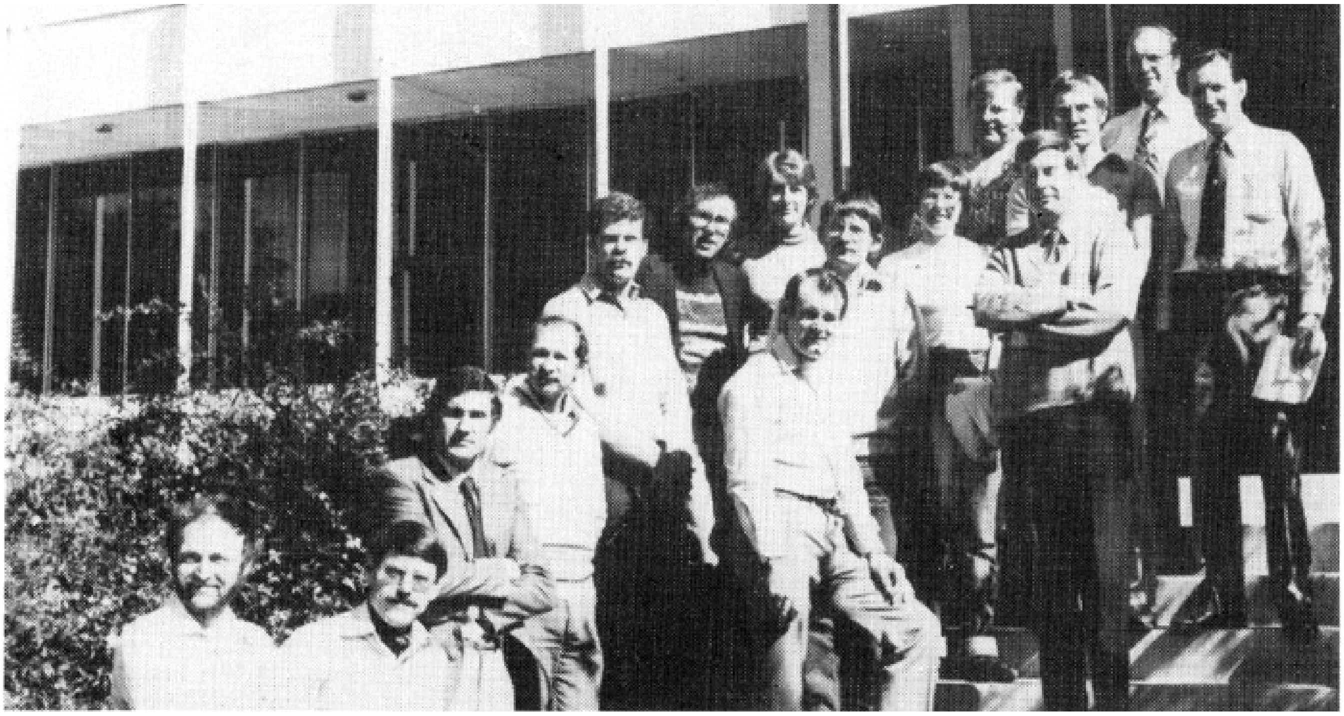


At this time, I was trying various cockpit aids to help me fly efficiently, and I was talking to other pilots about my ideas. A Japanese pilot I spoke to at the 1980-81 Waikerie National Championships was "Hiro" Ichikawa. When Hiro was interviewed by the magazine "Tsubasa" ("Wings"), they published this cartoon. Hiro assured me that the "Analytical pilot" was me, and the "Natural pilot" was John Rowe (who placed second to Shane McCaffrey).

The Use of Water Ballast

By Garry Speight

This material first appeared as a talk I gave to the Second National Soaring Symposium, Canberra, September 1980. The title was "Just what does ballast do for you?"



This photo includes many of those members of the Gliding Federation who were prepared to speak about soaring theory and practice at that time, such as: John Buchanan, Garry Speight, Maurie Bradney, David Pietsch, Mike Giles, Sue Martin, Barry Wrenford, Mike Borgelt, Bob Ward, Dafydd Llewellyn, Harry Walton, and Roger Woods.

It was published in "Australian Gliding" September 1982, and re-published much later in "Keep Soaring", May-June 2011.

The performance of a sailplane is usually expressed by a curve showing the way that the rate of sink varies with forward speed. This is called the performance polar, although it is not nowadays plotted using polar co-ordinates.

The performance polar for the Astir CS (Ref. I) is shown in Figure 1a, plotted in the customary way, with airspeed in knots along the horizontal axis and rate of sink, also in knots, plotted at a much coarser scale on the vertical axis, reading downwards.

There are three key features on this curve. The highest point of it is the point of minimum sink: this corresponds to a minimum sink rate on the vertical axis (1.34 knots) and a speed for minimum sink on the horizontal axis (44 knots).

As the airspeed is reduced below this figure the sink rate increases more and more rapidly until at the stalling speed the curve is going just about straight down.

On the right hand side of the curve, as the airspeed is increased above that for minimum sink, the sink rate increases rather slowly at first so that for a time the glide angle actually gets flatter, down to a point called best glide which corresponds to a best glide speed on the horizontal axis (50 knots).

The ratio of this speed to the corresponding sink rate on the vertical axis (1.43 knots) is called the best glide ratio (35:1) At higher speeds the glide angle become increasingly steep.

The Use of Water Ballast

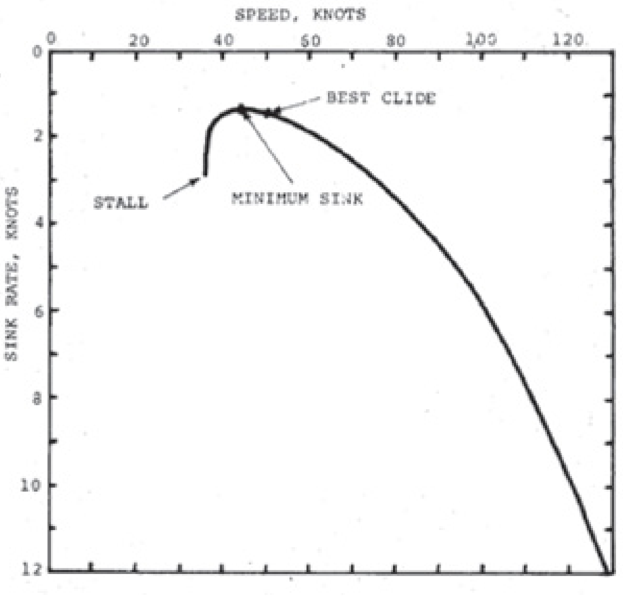


Fig 1a.

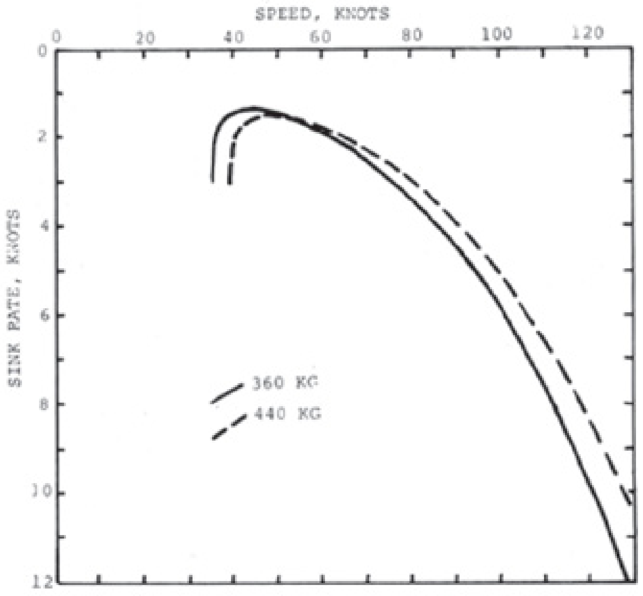


Fig 1b.

By tradition, because lightness of construction used to be highly regarded, test flying for polar curves is done at the minimum practical loading of a sailplane that is, its empty weight plus about 100 kg of pilot, parachute and instruments.

If a glider is more heavily laden as by adding ballast, its performance polar will not the the same: every point on the curve will move both to the right and downwards by the square root of the ratio of the heavier weight to the test weight.

Figure 1b shows the performance polars of the Astir CS at 360 kg weight near its minimum practical loading, and at 440 kg weight, a little below its designed maximum loading.

The ratio of these two weights is 1.22 Since the square root of this ratio is about 1.10, or 110%, each point on the second curve is obtained by adding 10% to both the airspeed and the sink rate of a point on the original curve.

According to this formula (which is little over-simplified) the stalling speed, the speed for minimum sink and the best glide speed will all go up by 10% and so will the minimum sink rate, while the best glide ratio will remain just the same as it was.

By increasing the weight of the glider, we have made it a higher-speed machine. During the sixties many pilots became convinced, whether by “gut-feeling”, by comparison flying, or by calculation, that adding weight to their gliders was an advantage in cross-country soaring, particularly when the thermals were strong.

Some carried lead, and the more ingenious began to carry water which could be jettisoned if slow-speed performance became vital.

Some experts were sceptical of the value of water ballast but the idea caught on so well that by 1971 most of the high performance gliders in production had provision for it, and it had even been specifically permitted under the Standard Class rules.

The reason why ballast confers an advantage in cross-country flight is not immediately obvious, and I believe that many pilots rely on a vague idea that a faster best glide speed must somehow produce a faster cross-country speed through MacCready speed- to-fly theory.

Actually, it may be an advantage to carry ballast on a day when simple MacCready theory predicts that unchanged inter- thermal glide speeds and slower average cross-country speeds will result, given the prevailing thermal strength.

The key to the problem is that the most important effect of carrying ballast on the performance polar is not that the curve shifts to higher airspeeds, but that the two curves cross each other (at 52 knots) so that the ballasted glider sinks more at the slow airspeeds used for thermalling and sinks less at the high airspeeds used for cruising (Figure 1b).

Ballast and MacCready Speed

The effect of ballast on cross-country performance may be studied using the thermal models developed in the article “Rate of Climb in Thermals” (Ref. 2) and the thermal interception diagram (Ref. 3).

The thermal interception diagram (Figure 2a, 2b, 2c) is constructed from the performance polars (Figure 1) using an arbitrary thermal spacing of 10 nautical miles.

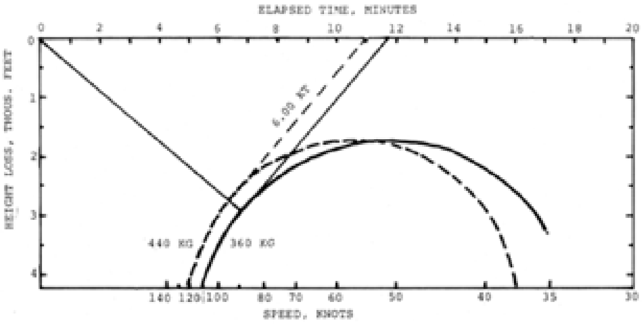


Fig 2a.

Figure 2a (above) shows how, if the pilot flies at the correct MacCready speed to a thermal yielding a particular rate of climb (6 knots), the ballasted glider has both a higher optimum glide speed (as read on the bottom scale below the point of arrival at the thermal) and a higher cross-country speed (as read below the point of return to the starting altitude).

The comparison for equal rates of climb, is, however, quite misleading, as we wish to compare performance in the **same** thermal. The rates of climb will then differ, with the unballasted glider able to climb faster.

In “Rate of Climb in Thermals” it was concluded that, if a ballasted Astir CS were flown in a “normal” thermal (requiring less than 40° of bank), the effect of jettisoning 80 kg of ballast would be to increase the rate of climb by 0.50 knots. In a “narrow” thermal (requiring 45° of bank) the climb rate would go up by 0.84 knots.

In discussing the use of ballast, it seems more sensible to take the case of the ballasted glider as the standard for comparison, using round numbers for its rate of climb. In a ballasted glider one can take a decision whether to dump or not; in an unballasted glider there is no decision to be made!

Figure 2b shows the MacCready construction for a thermal that yields 6 knots climb rate for the ballasted glider and 6.5 knots for the unballasted glider if the thermal is of normal diameter, or 6.84 knots for the unballasted glider if the thermal is narrow.

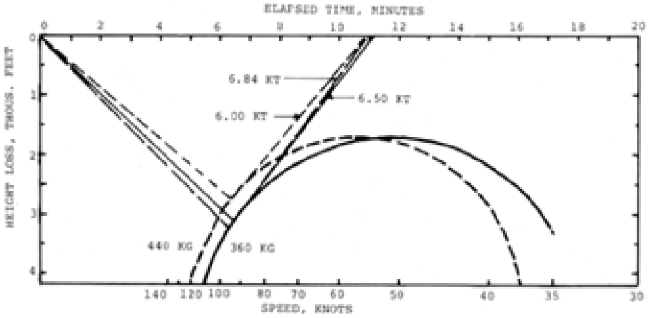


Fig 2b.

It is clear from the reduced gap between the points where the gliders arrive back at their starting altitude that the speed advantage of the ballasted glider is not nearly as large as appeared in Figure 2a, and is particularly small if the thermal is narrow, because of the relatively rapid rate of climb that is possible without ballast.

Figure 2c shows how, in a thermal yielding 2 knots rate of climb (ballasted), the glider’s better rate of climb after dumping ballast increases the cross-country speed, especially if the thermal is narrow.

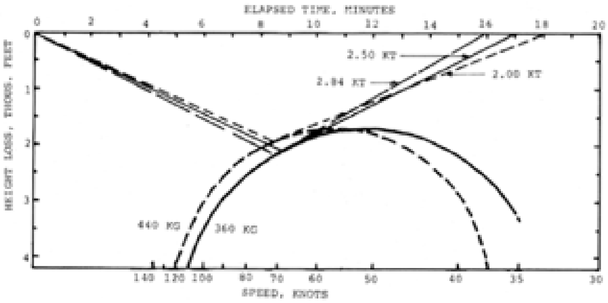


Fig 2c.

By plotting the cross-country speeds in this way for various thermal strengths we can construct Figure 3. This shows that, for normal thermals, dumping ballast will yield a speed advantage if the rate of climb is less than 3.2 knots and this advantage increases rapidly with weaker lift, until at 1 knot it is 20%.

When the rate of climb is greater than 3.2 knots it is better to carry ballast but, even in very strong conditions, the speed advantage does not amount to 5%. If the thermals are narrow the break- even point comes at 5 knots climb rate.

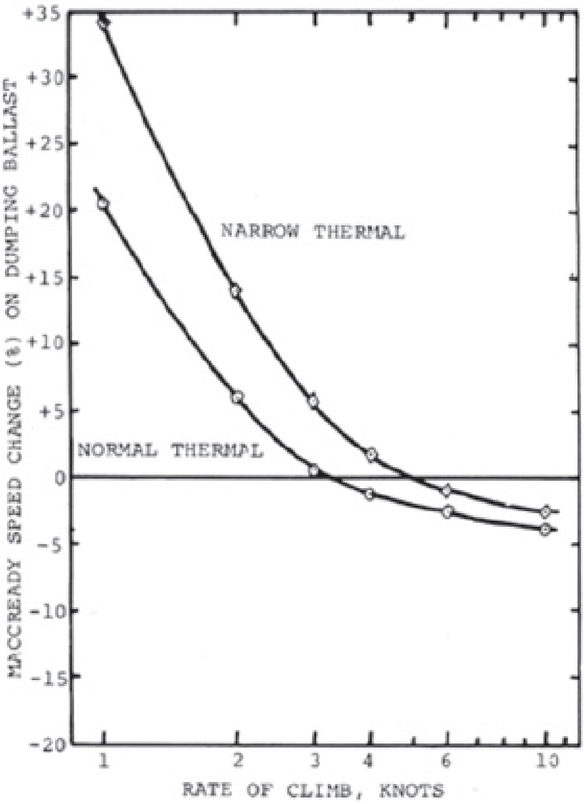


Fig. 3. Change in cross-country speed resulting from dumping ballast versus rate of climb (ballasted) for the Astir CS in normal and narrow thermals according to simple MacCready theory.

The speed advantage of carrying ballast does not exceed 3% even in strong conditions, whereas the advantage of dumping ballast in weak conditions goes as high as 35% for a 1 knot climb rate.

So far, ballast scarcely seems to be worth all the trouble and expense.

Dolphin Soaring

Herbert Pirker of Vienna wrote a paper on this subject which he presented to OSTIV in Finland in 1976 (Ref. 4). His approach was much more comprehensive but, in part, his results agree very well with mine.

He took the case of the DG100 which has a higher wing-loading than the Astir CS so that its performance polars are a little further to the right. However, the ratio of ballasted to unballasted weights is much the same. Unballasted, the Astir CS wing loading is 29 kg/m2 against the DG100's 30 kg/m2 ; ballasted, the figures are 36 kg/m2 and 38 kg/m2 .

Pirker used a Konovalov Type B thermal model to simplify calculations but, of the four thermal sizes that he quoted in his results, the two narrower ones, "Grad 0.015 sec-1," and "Grad 0.03 sec-1, are closely equivalent to my "normal" and "narrow" thermals respectively, requiring 40° and 46° of bank for best climb when ballasted.

The break-even points for dumping ballast were calculated as 3.4 knots and 5 knots respectively.

However, Pirker was concerned with analysing the effect of dolphin soaring on the decision to carry ballast.

To do this he introduced a term called "thermal density" which he defined as "the sum of the gliding paths in the up-drafts, divided by the whole distance" expressed as a percentage. This does not include the thermals used for circling, but only those that are flown through dolphin-fashion on the glides.

The higher the thermal density and the stronger the lift the less circling is required. Pirker found that no circling at all would he necessary if 20% of the sky was going up at 10 knots or if 50% of it was going up at 3 knots.

Figure 4 is re-drawn from the part of Pirker's Figure 19 equivalent to a "normal" thermal, and shows the change in cross-country speed of a DG100 that would result from dumping ballast, not only for the circle-and-glide case, but also for mixed circling and dolphin soaring with thermal densities of 30% and 50%.

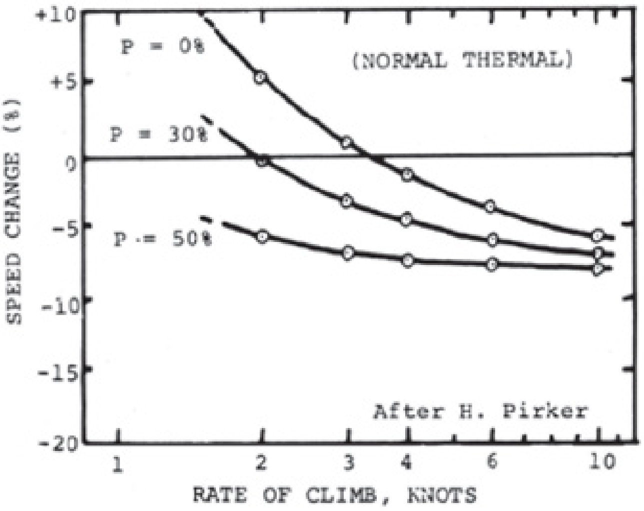


Fig. 4. Change in cross-country speed resulting from dumping ballast versus rate of climb (ballasted) for the DG100 in a normal thermal with varying thermal density (after Herbert Pirker).

This shows a substantially greater benefit for the ballasted glider when dolphin soaring is possible amounting to more than 7%, even in rather weak lift conditions, provided that the thermal density is 50% or more.

Unfortunately, I cannot agree that Herbert Pirker's analysis accurately represents the sky. My barograph traces indicate very low thermal densities. I estimate a typical value of 4%.

Perhaps truly skilled pilots can push the figure up to 10%, but I am sure that the influences of thermal density on decisions to load up or dump ballast must be very small.

Thermal search range

I believe the advantages of ballasting to a high wing loading lie in quite a different direction: in increased range as it relates to the varying spacing and varying strength of thermals.

Looking again at Figure 2b, we can see that, whereas the ballasted glider, in this particular ease, loses 2,750′ on the way to the thermal, the unballasted glider, also flying at optimum MacCready speed to the same thermal will lose 3,100′ or 3,200′, depending on whether the thermal is normal or narrow.

(The normal and narrow thermals should perhaps be on separate diagrams: the narrow thermal must actually be a stronger thermal for the ballasted glide to achieve the same rate of climb in each. That is why the unballasted glider loses more height in getting to the narrow thermal.)

Thus the height lost on this glide would be 11% greater after dumping ballast in the case of a normal thermal and 14% greater in the case of a narrow thermal. A lightened glider is very much worse at conserving altitude than a heavy one.

Since we usually do not know where our next thermal is, an 11% increase in height lost over a given distance may more usefully be thought of as an 11% decrease in range for thermal search. To use traditional term, it is a decrease in penetration.

Points plotted on thermal interception diagrams like Figure 2 can be used to produce curves showing how the reduction in thermal search range varies with climb rate: Figure 5.

This figure indicates that the variation is rather small, with an apparent minimum at the figures already given for a 6 knot climb rate.

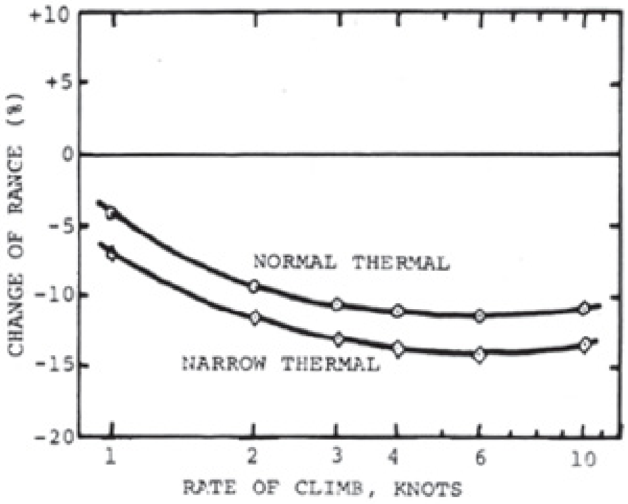


Fig. 5. Change in thermal search range resulting from dumped ballast versus rate of climb (ballasted) for the Astir CS in normal and narrow thermals.

Consequences of reduced range.

How important is this reduction in search range? This depends on some estimates about the way thermals of different strengths are scattered around the sky.

First there is the matter of whether we are going to make it to the next thermal. In a current type of Standard Class glider we will be flying at a glide ratio of about 25:1.

Now the evidence of a number of barograph traces is that the average spacing of thermals encountered on cross-country flights is about seven times the depth of convection. This means that, if we make some allowance for circuit height, a glide from the top of the convective layer will intersect three thermals on the average. But we know that the spacing of thermals commonly varies from half as wide to twice as wide as the average so, on every inter- thermal glide, even one from the top of the convective layer, there is a very real chance of having to land out. An 11% increase in range could prove very useful indeed.

Next, there is the matter of “scratching”: desperately holding height in zero sink at low altitude, waiting and hoping for a useful thermal to break loose. This situation will arise 11% less often for a glider carrying ballast.

The loss of time while scratching can be very large: ten minutes in a 200 minute race is a 5% reduction in speed, equal to the disadvantage already demonstrated by Figure 3.

Finally, there is the variation in thermal strength. Cross-country races are won by the pilot who spends the most time in the strongest lift. Mediocre lift is to be used only to get enough height to resume the search for the very best lift.

When you have dumped your ballast and have lost 11% of your search range you are committed to circling in 11% more thermals. These will not be boomers that the other pilots have missed: they will be the rags that they did not bother to circle in.

This is the answer to the old riddle of how the hotshots of yesteryear, with lead cushions in their Boomerangs, always seemed to find better thermals than anyone else: better penetration allowed them to reject the weak lift and press on with the search for the very best.

Some may argue that you do not have to lose all that height; you can fly at a lower ring setting. Provided that the ring settings mentioned so far have all been realistic settings, this policy will surely slow you down just about as much as if you repeatedly got too low.

Without more information and more detailed analysis, one cannot accurately express the effects of reduced search range as a quantitative reduction in cross-country speed.

However, I believe that the effects are at least in proportion: an 11% range reduction producing at least an 11% reduction in speed. So one can take a stab at the combined effects of MacCready speed ratio and search range ratio by multiplying them together, with the results shown in Figure 6.

According to this estimate, ballast can yield a 15% advantage in achieved cross- country speed in strong thermal conditions. The break-even point comes at about 1.6 knots climb rate, or 2 knots climb rate for narrow thermals, but it is still much better to be without ballast in 1 knot thermals.

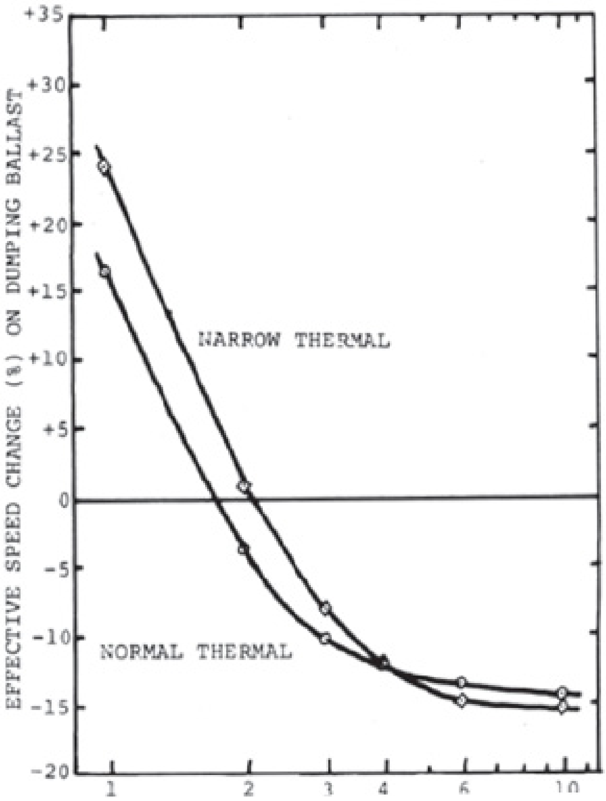


Fig. 6. Estimated total effective change in cross-country speed resulting from dumping ballast versus rate of climb (ballasted) for the Astir CS, combining the effects of MacCready speed and search range.

Tactics

If search range is an important feature in the use of ballast, it follows that one should not dump ballast during the thermal search, even at low altitude. You will only reduce your search area, and you may still find a thermal strong enough to justify keeping it on board.

The time to dump it is when the lift that you are working at 800 feet is not much better than zero sink. A social problem may then arise if another glider comes to circle below you(!),

Having once been guilty of dumping water on another, I think I have the answer: either he has already dumped, or he soon will (unless there is someone below him). He should be able to climb through you and it may be possible, with his assistance in finding the centre, for you to climb quite well without dumping the water after all.

Daan Pare mentioned that European pilots have discussed the point as to whether you dump the ballast the first time you have to scratch, or the second, or the third... Clearly it depends on how much value you expect to get out of the ballast after you have struggled up again.

When climbing for final glide, search range is no longer relevant and the simple MacCready argument applies.

If you are climbing for final glide in a 2 1/2 knot thermal, dump the water, change the MacCready ring or speed director to “dry”, set your increased rate of climb on the final glide computer, also on the “dry” scale, and go home in the minimum time.

Other aircraft

The comparative cross-country performance of various types of current Standard Class glider depends largely on their wing-loading. Differences in stalling speed and minimum sink rate when measured at the same wing- loading are scarcely significant.

Advantages in best glide ratio definitely favour certain of the latest types but these can he negated by inappropriate management of water ballast.

The latest models generally have provision for ballasting up to a loading of about 45 kg/m^2, and the Mini-Nimbus is designed to take 51 kg/m^2. Whether the advantages of ballast continue to increase up to that figure I have not attempted to find out.

I am fairly sure that the limitation of the Astir CS and the Standard Libelle to only 36 kg/m^2 is a definite handicap. No manufacturers of competition gliders are now bothering with minimum wing loadings less than 31 kg/m^2: the LS 1f has a minimum of 34 kg/m^2!

The Americans, with their cavalier attitude to loading limits, have apparently found performance benefits in loadings substantially greater than the manufacturers allowed for.

We would do well to find out more about the relationship between performance and wing-loading. We should be analysing championship results, and we should be collecting data on the size, strength and distribution of thermals.

It would also help if glider designers spoke out on what they are trying to achieve and why they think it will work.

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3. The Thermal Interception Diagram, by Garry Speight. Australian Gilding, April 1981, pp. 4-8.
4. Some Computer Calculations on the Optimum Waterballast of Sailplanes, by Herbert Pirker, Swiss Aero Revue 3/77 (1977), pp. 173-178.

The Great Man himself...Garry Speight, known internationally as "that Kiwi who can thermal a fart" standing in full regalia in front of the modern equivalent of an Astir CS.

(Photo and caption with the re-published article in "Keep Soaring" May/June 2011)

Thermal Density

By Maurie Bradney

Originally published in Australian Gliding, March 1983

Dear Sir,

I must congratulate Garry Speight on his excellent article in September 'A.G.' on water ballast.

However, I believe he has made an error where he discounts the benefits in the dolphin soaring area. In his 2nd paragraph, 1st column, page 20 he says:

"This shows a substantially greater benefit for the ballasted glider when dolphin soaring is possible, amounting to more than 7%. even in rather weak lift conditions, provided that the thermal density is 50% or more.

"Unfortunately I cannot agree that Herbert Pirker's analysis accurately represents the sky. My barograph traces indicate very low thermal densities. 1 estimate a typical value of 4%.

"Perhaps truly skilled pilots can push the figure up to 10%, but I am sure that the influence of thermal density on decisions to load up or dump ballast must be very small."

This is one area where I believe Australian pilots fall down badly. We have been using the "straight" McCready system for so long we are blind to the alternatives. On the first ever completed 1000 km triangle Hans Werner Grosse covered the first 300 kms all below 3,000 ft. and averaging over 100 kph. He did this mostly by dolphin soaring, with only occasional circles in the stronger cores.

Having had the pleasure of flying with him in the two-seater and also in company in single seat sailplanes, he uses this technique extensively to make excellent speeds, particularly on the lower ceiling days.

An aid to achieving this is a good Netto variometer. It is used more in the negative sense, that is to avoid sinking areas, rather than as a thermal finder. The result is that it usually does lead one to thermals.

A good knowledge of cloud and ground reading for thermal sources and triggers also helps.

In this manner we at Waikerie have found it possible to increase thermal density consistently to 20%, which more than offsets the small additional distances covered.

Also, on good days it is possible to achieve speeds faster than the MacCready indicates is possible. I believe this is an area where there is a large amount of knowledge to be gained for the improvement and enjoyment of our sport.

Maurie Bradney, Waikerie, SA

Water Ballast

By Garry Speight

Originally published in Australian Gliding, May 1983

Dear Sir,

I would like to thank Maurie Bradney for his comments on my article about the use of water ballast. I was very gratified to find that a pilot of his talent and international experience thought that it made sense, as the effect of ballast on thermal search range does not seem to have been discussed before.

I agree with Maurie that a pilot who can increase the thermal density on his track by superior skill in locating lift has an enormous advantage, although I believe this is a part of MacCready flying, not something separate from it.

The only point that I had intended to make about dolphin soaring was that a pilot is not likely to reason as follows: “The lift won’t be strong, but there are likely to be cloud streets: that means dolphin soaring, so I’ll load up ballast”. I believe that most gliders will make better speeds if they are loaded to the legal limit on any reasonably soarable day, regardless of whether the day offers especially good prospects for dolphin soaring.

Flatter glide angles permit more extended use of dolphin soaring, and it may well be that Herbert Pirker’s calculations are relevant to the optimal wing loadings for super-ships. Perhaps they should be designed for rather higher wing loadings than current standard class gliders that need to stop and circle more often.

I was very sorry to hear of Maurie’s accident, and I would like to wish him a speedy recovery.

Garry Speight O’Connor, ACT

Garry (third from left) with 1992 course participants

Sheep, Goats, and Water Ballast

By Garry Speight

By 2011, my 1982 article "The use of water ballast" and discussion about it had faded from memory, with hardly anyone convinced. At a regatta at Lake Keepit in 2011 I tried once again to tell people that the usual talk about the benefits of water ballast was not correct. Because I rushed this presentation, I was misunderstood by many people present. I wrote the following letter to "Keep Soaring" and to "Gliding Australia" about it. In response, John Clark, very kindly re-published my 1982 article for the new generation in "Keep Soaring", May-June 2011. I then amended my letter to "Gliding Australia" to acknowledge John's action, as below.

Originally published in Gliding Australia, January/February 2012

John Clark, with his usual sharp wit, described a recent Lake Keepit Regatta in the April 2011 "Soaring Australia" (p. 30-32) in an article "Separating The Sheep From The Goats".

In it he summarised a talk I gave on the effect of water ballast on performance. Unfortunately, he left out the punch line (perhaps I muffed it somehow). This gave the impression that I do not recommend carrying water ballast, when in fact I do. The advantage is simply not what people think it is.

My talk was a brief version of an article I wrote in the distant past: "The Use of Water Ballast", Australian Gliding, September 1982, p.16-22. I am sure that my argument was correct then, and is still correct. Wing loadings are all heavier now, so someone should update the calculations and graphs leading to the conclusions of my article.

John Clark has since earned my gratitude by kindly re-publishing my ancient article where it can be read by a new generation of glider pilots: the Lake Keepit soaring Club on-line magazine "Keep Soaring" for May - June 2011 (see pages 33 to 37): http://www.keepitsoaring.com/LKSC/Downloads/Keep_Soaring/May_June_2011.pdf

To quote John Clark's article (with the points numbered):

"Garry Speight gives a challenging talk on why increasing your wing loading with water ballast

(1) will give you a lower rate of climb

(2) will give you more trouble in narrow thermals and

(3) won't make your speed on the glides any faster.

As usual with Garry's talks, it provoked some amusing arguments and more than a little scratching of heads."

These three points were supposed to lead to the up-beat conclusion:

(4) will stop you from getting too low.

The argument is this:

The advantage of a high wing loading is not directly related to all points on the polar (including best glide) moving to the right. It is related to the fact that a loaded glider sinks less at all the high speeds used for cruising, although it sinks more at all the slow speeds used for climbing.

When thermalling with ballast, the rate of climb is reduced for two separate reasons: the glider sinks more at each speed, and the minimum circling speed is higher, forcing a bigger circle which may be outside the thermal core. The best reason to dump ballast is finding that the glider cannot fly within the core.

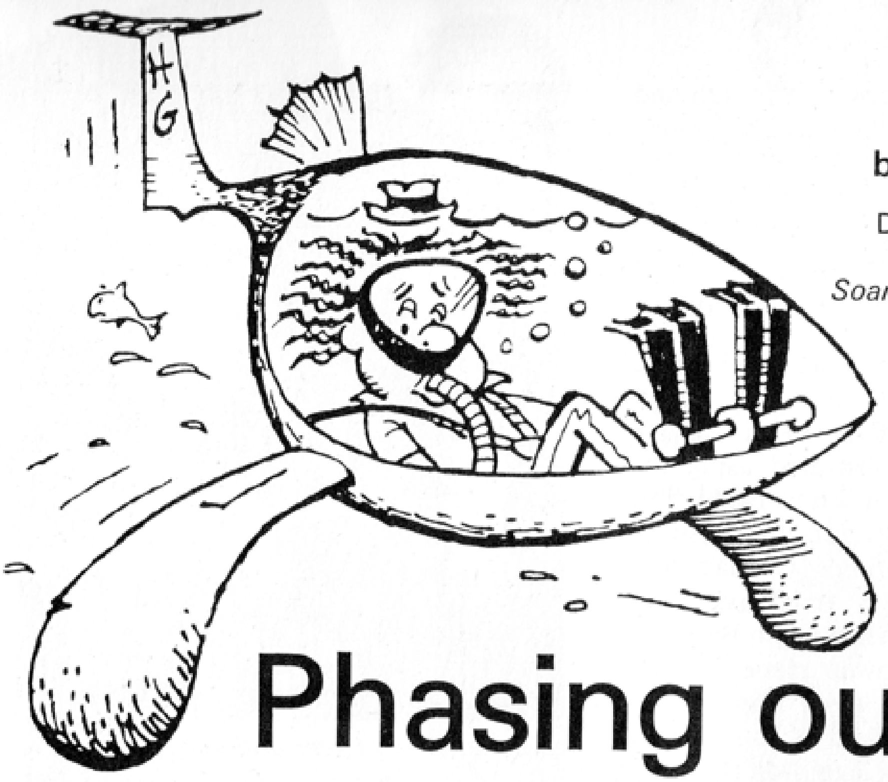
The best speed for cruising depends directly on the rate of climb. Pilots carrying ballast will fly at much the same speed as those not carrying ballast. If they experienced the same rate of climb, their better polar would justify a higher speed, but they don't; they experience a much lower rate of climb.

Given that ballasted and un-ballasted gliders should cruise at much the same speed, it is clear that the heavier glider's lower sink rate in cruise is its only advantage.

It is a very great advantage: the flat glide angle brings strong thermals within range, avoids scratching at low altitude, and makes outlanding less likely.

Garry's LS4a in which he won competitions

Garry winning in Queensland, 1991



Phasing out water-ballast

by Garry Speight

Drawing by Gil Parcell, used by courtesy of *Soaring* magazine, U.S.A.

Originally published in Australian Gliding, February 1985

The June 1984 issue of Soaring carried an article by Wil Schuemann proposing that water-ballast should be eliminated from gliding contests. It was reprinted in January AG.

Schuemann's knowledge of water- ballast may be judged from the fact that he flies a clipped-wing ASW12 that has the highest wing loading of any 15-metre sailplane, 55 kp/m^2, with water-ballast making up 38% of the all-up weight.*1

Schuemann gives many good reasons why water-ballast has outlived its usefulness and is not worth the various dangers that it brings.

I agree with him. However, I don't agree with his solution, which is also being tried in Australia: to fly contests in existing gliders without their water ballast. Gliders are to be raced at the very low wing loadings intended only for desperate saves when the sky falls in!

I expressed my view in the following letter sent to Soaring magazine:

Dear Sir,

I support Wil Schuemann's brave statement about water ballast. The value of water ballast in competition gliders no longer justifies its many dangers and technical and administrative problems. We should stop using it.

How can we do this without hurting glider owners or manufacturers? So far as possible, existing gliders should not be devalued as competition aircraft.

Wil Schuemann's idea of promoting unballasted competitions using existing gliders is not the answer. These gliders were not designed to race against each other without their ballast.

Some of the most expensive ones are too lightly loaded, whereas Hornets and LS-1's, with unballasted wing loadings exceeding 34 kp/m^2 (7 lb/sq ft), have an unforeseen advantage.1

Since the heyday of the Sisu it has been clear that competition success seldom depends on being able to reduce the wing loading below that value.

Phasing Out Water-Ballast

The performance benefit of a high wing loading is not even closely related to thermal strength, but is mainly due to an increase in thermal search range at the appropriate MacCready speed. I doubt that pilots will be happy to forego the flat glide angles that they are now accustomed to.

I believe that the first step towards eliminating water ballast should be to arrange competitions at a fixed wing loading.[2] In due course, a wing loading value should be included in class definitions.[3]

It should be made mandatory to display correct weight and wing area values in each competing glider. Also, the dumping of water ballast in flight should be penalised so that the pilot derives no advantage from it.

These steps would remove the incentive for manufacturing water-ballast-carrying aircraft. However no existing aircraft would be rendered non-competitive in the process.

The Standard Class, traditionally the "no-frills" class, should be the first to move away from water ballast. I suggest that the appropriate wing loading value should be 36 kp/m^2 (7.5 lb/sq ft). A higher value than this would permit higher cross-country speeds on good days, but it would also prevent competition on weak days.

All current Standard Class gliders can achieve this loading, although the Standard Libelle and Astir CS are then at their maximum permitted weights.4

A competition between Standard Class gliders all flown at 36 kp/m^2 might reveal a remarkably small range in achieved performance.

Glider-weighing at serious competitions is with us already. At first, the only change would be to verify a common wing loading rather than a certified maximum all-up weight.

In the course of time, weighing would be replaced by a check of documentation and an inspection for unauthorised ballast. Perhaps the pilot, with his equipment and trim weights might be weighed.

While water ballast is still being carried, we will need a way to monitor the "no dumping" rule. If dump valves were modified to prevent them from being reclosed, then any pilot who could not stream ballast at the finish line could be assumed to have dumped it during the race.

Once the competitive advantage of carrying water had been removed, glider owners could decide whether to retain their hazardous water ballast systems or to carry out authorised modifications to install fixed or removable solid ballast. Perhaps this could take the form of flexible rods, to be inserted in pockets beside the spar.

Manufacturers may favour installing some form of removable ballast, so as to be able to convert a Standard Class competition glider to a training glider with a wing loading of 29 kp/m^2 (6 lb/sq ft) or less.

In the 15-metre Class, the use of flap permits the circling speed to be reduced by about 10% at a given wing loading.

If Standard Class gliders can stay aloft at 36 kp/m^2, then 15-metre Class gliders should stay aloft at a wing loading that is some 20% higher, i.e. 44 kp/m^2 (9.5 lb/sq ft). These values are put up just as a starting point for discussion.

The Open Class logically is the place for experiments aimed at improving sailplanes in general. In my opinion it should be free of all arbitrary restrictions. The people involved should take responsibility for developing safe procedures and for obtaining adequate tugs and airports.

In the case of the other two classes, I imagine that designers would welcome the opportunity to aim for the ultimate in aerodynamic efficiency at a specified wing loading. Designing for a variable wing loading must make it difficult to produce an optimal aircraft.

Including wing loading in a competition class definition would guide sailplane development according to pilots' needs. Simply banning water-ballast would give no such guidance. Without it, no two manufacturers will make comparable gliders.

Phasing Out Water-Ballast

Notes:

*1 "Throughout this article we use the abbreviation kp/m^2. This indicates kiloponds per square metre and is the current terminology for referring to wing loading. As it happens, though, a kilopond force is the same as a kilogram mass so those who prefer can continue to think in kilograms per square metre. Wing loading should properly be expressed in Pascals."

1. I don't actually know the maximum wing loadings permitted in various types when flown without water-ballast. Perhaps some of them can carry a lot of lead (or a pilot fed like a sumo wrestler) to enhance their performance if water-ballast is banned.

2. When I say a fixed wing loading I mean no more and no less. Lightening up the aircraft on a weak day should not be allowed.

3. It has to be wing loading rather than weight that is standardized. Wing loading governs the performance, and wing areas may vary by 15%.

4. Full of water.

Since this was written, two things have changed. First, top pilots, who once disdained any glider not of the highest performance, now compete in low performance gliders in the handicapped Sports Class or Club Class. They are now happy to show their skills flying without water ballast. Second, "assigned area" tasks have become common in competitions. Because pilots flying low performance gliders are not now required to fly as far as those in higher performance gliders, they are not as prone to out-landing as they once were.

Canopy Marks for Attitude Control

By Garry Speight

Originally published in Australian Gliding, August 1986

Also published in Soaring, April 1987

In a turn, the airspeed and the rate of turn have to be kept steady. At the same time, the yaw has to be matched to the bank to avoid slipping or skidding.

Nearly all glider pilots learn how vital these things are in their first hour in the air. Then they spend the next thousand hours or more trying to get them right!

A glider pilot must be much more aware of flying errors in turns than the pilot of a light aeroplane. Once the glider pilot allows the aircraft to stray from its proper attitude, a stall or spin may be only seconds away.

Most turns in gliders are thermalling turns. They are made at airspeeds slow enough for gusts to have a big effect. The margin above the stall is only 5 or 10 knots. This compares with a margin of 30 to 60 knots for typical turns in a light aeroplane.

This problem is not likely to go away. Thermals are not big enough for high-speed circling, and the stalling speed of gliders is not going to get less while glider pilots want to go further and faster.

Even turns in the circuit are made within 20 knots of stalling speed. Higher circuit speeds would reduce the time available for looking, thinking, and correcting, and could mean arriving at ground level with too much energy to get rid of within the length of the field.

Speed control at low speeds is not easy. Thermalling turns are made at speeds below the speed for best glide angle. This is the speed for minimum drag.

Pitch correct for 50 knots, roll correct (45˚), yaw wrong (slipping)

Canopy Marks for Attitude Control

Pitch wrong (nose too high) , roll correct (45˚), yaw wrong (slipping)

Pitch correct, roll wrong (only 40˚), yaw correct

Canopy Marks for Attitude Control

At thermalling speeds, any momentary decrease in speed due to turbulence or clumsiness increases the drag, which lowers the speed even more.

Conversely, increasing the speed decreases the drag, causing the speed to increase further. That is to say, the glider's speed is unstable.

At speeds above the best glide speed the glider speed is stable, because more speed brings more drag and less speed brings less drag.

At such high speeds there is no problem with speed control. The glider will "fly itself". This is just as well, for it takes a much smaller change in pitch angle to go from 90 kt to 95 kt than it does to go from 40 kt to 45 kt.

At slow speeds, gliders may be unstable not only in airspeed but also in roll and in yaw. Furthermore, the control surfaces all have less effect than they do at higher speeds. It is no wonder that skilful turning comes only with hours of practice.

When the glider stalls or spins, the pilot is likely to realise that there has been some error. Short of such alarming events, if the glider is not under proper control, climbing is largely a matter of luck.

The pilot can hardly learn much about thermals. A clear picture of the pattern of lift emerges only when the glider is doing almost-perfect circles at a steady speed.

The key to controlling a glider is **perception**, being able to notice the glider's attitude in the sky.

The aim of holding a steady speed and a steady rate of turn is achieved only by checking errors in the attitude of the glider: the height of the nose, the angle of bank and the presence of slip or skid, in other words, one checks the **pitch**, the **roll**, and the **yaw**.

Control in pitch

It is very difficult to control the speed by using the airspeed indicator (ASI) alone. The airspeed jumps about so wildly in thermal gusts that there is no point in trying to correct for them.

More important, the airspeed is slow to respond to errors in pitch attitude. If the nose is too high the speed will only slowly fall off.

When the airspeed error is noticed, the stick can be held forward until the airspeed returns to normal, but by that time the nose will be very low and the speed will continue to increase, becoming far too high. Then the stick will have to be pulled back, and so on.

If one has to fly in cloud on "limited panel" (i.e. with no Artificial Horizon), pitch attitude must be controlled using the ASI alone.

Then one must learn through long practice how to avoid these "pilot induced oscillations". For visual flight it is far better to look out at the horizon, glancing at the ASI only now and then to confirm that you have the airspeed value that you want.

In any case, having one's eyes glued to the ASI, or any other instrument, is bad. There may be other aircraft nearby, or the airfield may be passing out of range.

To control the airspeed, first control the pitch angle. Control of pitch is best achieved by relating the height of the nose of the glider to the horizon.

Control in roll

The banking or rolling of the glider is also most easily controlled while looking at the horizon in front of the nose. One learns to notice how much the horizon is tilted compared to parts of the glider.

Looking sideways along the wing is little use. One knows that the angle between the wing and the horizon is the angle of bank, but the wing and the horizon cannot both be seen at a glance, being some 30° apart.

Control in yaw

When the glider flies sideways we call it **slip** or **skid**. Slipping is sliding sideways towards the lower wing and skidding is towards the higher wing.

To detect slip and skid, some genius invented the yaw string. This is sensitive and accurate, and can be placed just where the pilot should he looking: in line with the horizon ahead.

A slip ball, as used in aeroplanes, is less sensitive, and is kept down in the "office" with the ASI. The only problem with the yaw string is that it can go soggy and lifeless when above cloudbase or in rain.

The yaw string shows **errors** in yaw, rather than yaw itself. Every turn should have the right amount of yaw. Yaw can be perceived directly as the sideways movement of the nose against the horizon.

When thermalling one learns to correct for sideways gusts by using the rudder to keep the nose moving around the horizon at a steady rate. In a spin the very fast sideways movement of the nose can be perceived so strongly as to produce vertigo.

Canopy marks

If attitude control is best achieved by relating the glider to the horizon ahead , how can we tell just where the glider is pointing? The horizon is easy to see, but the glider is not, because we are inside it.

While we have a rough idea of the sense of "straight ahead", it helps to have something to take aim with — something well out in the nose of the aircraft, such as the front of the canopy frame, the compass, or the instrument panel cover.

An aiming mark should be far enough from the pilot's head so that the eyes don't need to be re-focussed, and so that movements of the head don't have much effect. The farther away it is, the better the aim can be.

Instructors in back seats have always had more distant objects to use as aiming marks than their unfortunate pupils in the front.

Naturally enough, the canopy area through which one looks at the horizon ahead is usually kept clear of any features within the glider, to allow the pilot an unobstructed view! Yet that part of the canopy is clearly the place where aiming marks should be put. In modern gliders with fully-faired canopies this surface is far enough away from the pilot's eyes.

Because I felt I needed an accurate reference for attitude in a turn, I tried putting various marks on the inner surface of the canopy to line up with the horizon ahead in a thermalling turn. The marks showed my attitude control to be very poor indeed. I was letting the angle of bank change by 10° from moment to moment, and I was failing to notice the difference between 30° and 40° angles of bank. By using the marks I have managed to improve.

In the course of trials on my Astir CS I managed to place the mounting point of the yaw string just on the horizon for thermal turns.

On the inside of the canopy I then stuck small pieces of coloured sticky paper in two lines at 45° to the plane of the wings.

These lines mark the correct position of the horizon in a turn at 50 knots with 45° of bank. The photos show the pilot's view of the marks in relation to the horizon.

One can clearly see small errors in pitch, roll and yaw, and correct them before they get any worse.

Pitch error is shown by the line of marks being above or below the horizon. Roll error shows as an angle between the horizon and the line of marks. Yaw error is made very clear by the way the yaw-string is not pointing at the zero mark on the centre-line of the canopy.

Canopy Marks for Attitude Control

I have since replaced the paper marks with slivers of red plastic insulating tape, and I have changed the angle of bank shown by the marks to 40°. I find that 40° suits most thermals, flown with or without ballast.

I very seldom see Standard Class pilots banking more steeply than that, although some open class pilots thermal at 50° — a great sight to see!

If I want to, I can keep the bank steady at 5° steeper or shallower than the line of canopy marks. For different speeds I can keep the marks just above or below the horizon.

I feel that more than one line of marks would not be useful enough to justify the extra clutter.

To know where to put the marks, one should find where the horizon cuts the centre-line of the canopy at normal gliding speed, say best glide speed.

Usually there is a yaw string already fitted, and one can note where it sits in relation to the horizon.

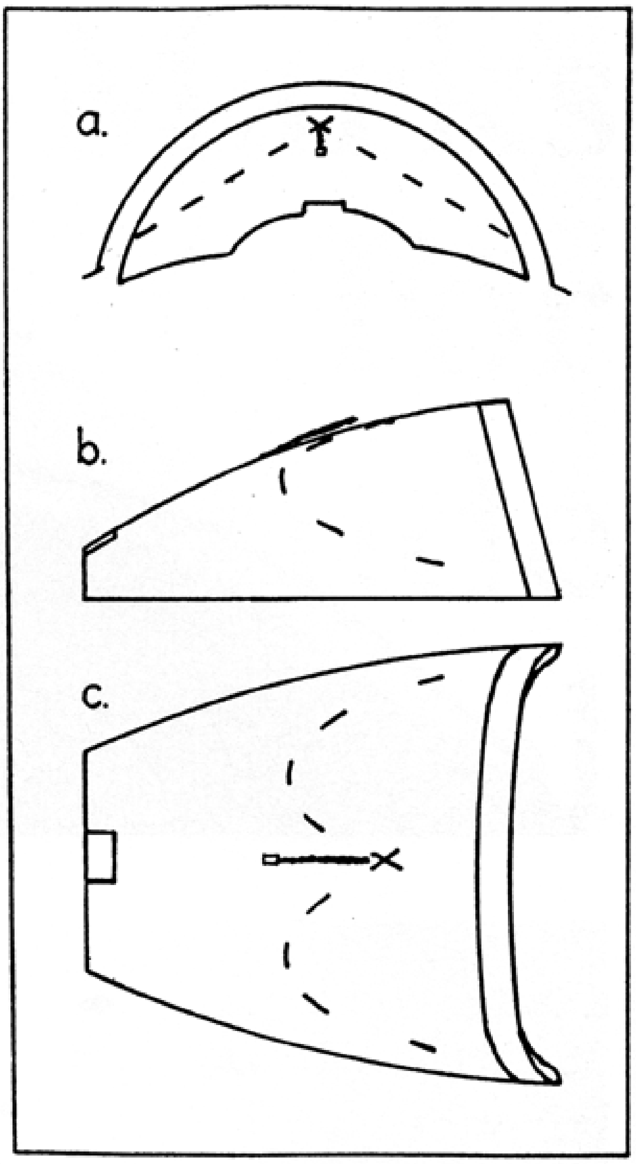
Then one end of the yaw string, the front end for choice, is shifted to the point where it will sit on the horizon. Then one must construct two sloping lines passing through this point.

A Douglas protractor can be set up on top of the instrument panel, with a ruler placed against it to give a line at the correct angle. If the panel is curved, some other way must be found to get a base-line that is in the plane of the wings.

A person sitting in the cockpit can direct a helper to draw the lines with a grease pencil on the outside of the canopy. Then, little rectangles of insulating tape (about 20 mm x 7 mm) are stuck at intervals along the lines on the inside, and the grease pencil marks are wiped off.

I use the canopy marks myself to improve and maintain my level of flying skill. I believe that they may also have a role in basic training.

If a pupil has a clear and certain “foresight” to line up with the horizon, he may not have to put up with so much nagging from the back seat: “You’ve let it bank too much! Now the nose is too low! We’re skidding! Don’t let it stall!” etc. etc.



Canopy marks for a Blanik for 30° banked turns; (a) seen from the pilots seat, (b) side view, (c) plan view

I have sketched the layout for canopy marks in a Blanik in the drawing. Clearly, the canopy bow badly obstructs the forward view of the front seat pilot. There is no room for the yaw-string above the horizon.

These marks are arranged to show a 30° bank angle. This angle is steep enough for thermalling, because the Blanik has a lower stalling speed than a Standard Class glider.

Canopy Marks for Attitude Control

It is also a useful bank angle for turns in the circuit area, although some pupils don't like to bank so steeply as 30°!

Depending on the speed, the marks may appear above or below the horizon, but they are close enough to the horizon to relate to it.

The idea is to keep them parallel to the horizon and a constant distance above or below it for the duration of the turn.

The height of the pilot's head in the cockpit has two effects. First, the marks may appear higher or lower for the same aircraft attitude. Second, due to the curve of the canopy, the marks will not form a straight line unless the pilot's head is in the right position.

This should not be a problem because all pilots heads should be at the same height! Pilots should sit as high as they can, so as to get the best view out of the glider.

I have found that pupils having trouble with landings are often seated too low. They improve dramatically when raised up on higher cushions.

A limit is set by the canopy over the pilot's head. Too close is dangerous and causes costly repairs. About two fingers (40mm) gap between the scalp and the canopy is best, so long as the harness is properly tight.

I have been concerned that people might find the canopy marks distracting but this does not seem to happen. On the contrary, when they are installed some pilots don't even see them for several flights!

I cannot say for sure that anyone has learnt more quickly or flies more accurately as a result of having canopy marks in our club Blanik. All the same, I think they must help towards better and safer flying.

Visit By Mitsuru Marui

By Garry Speight

Originally published in Australian Gliding, January 1992

This summer, Mitsuru Marui is coming from Japan to instruct for several months at Waikerie.

He and his friend Ikeda will devote themselves particularly to instructing Japanese visitors.

They are not expecting any pay, but they hope to do a lot of cross-country flying in their spare time.

I was delighted to hear of Marui-san's visit to Australia. I find him one of the most interesting and likeable of Japanese glider pilots.

He is an enthusiast for international goodwill, especially in the field of gliding. He hopes that his visit will be one step towards a systematic exchange of visits by Japanese and Australian glider pilots.

Marui-san is a very experienced gliding instructor. He has more than 1000 hours in gliders, mainly in Japan. If you have been to Japan, you will know that this is no mean feat!

His home base is at Takikawa, a town of 50,000 people in the northern island of Hokkaido,

Inland Hokkaido has about the best gliding weather available in Japan, although the latitude is 44°N. It also has fields just about big enough for outlandings (250m), and there is some airspace to fly in.

Marui-san works in the Department of Education of the Takikawa City Government as the aerosports clerk. His duties include being the manager and CFI of the Takikawa Skypark and Gliding Centre.

What it amounts to is that he has persuaded the city to throw its weight behind the gliding centre in a big way. He has also attracted support from businesses which have become corporate

Visit By Mitsuru Marui

members of the Sky Sports Association of Takikawa.

The gliding centre's airstrip is right next to the city centre. As is the custom in Japan, it is in the river bed between the flood-banks.

The club-house/hangar building is just outside the flood-bank.

Because this is Hokkaido, where the land is cheap, the gliders are hangared fully rigged. Two gliders are hoisted to the ceiling above three more gliders and the Robin tug.

During the past season Marui-san and his team have trained 70 glider pilots from other parts of Japan. For the future, there is an ambitious plan for the gliding site to be developed into a "Skypark" of national significance.

This will include not only facilities for gliding, ballooning and parachuting, but also an aerospace museum, amusement park, and general sports park.

The projected cost is about $4 million by 1996.

Marui-san is also researching the potential for cross-country gliding from Takikawa. He has been surveying routes by motor- glider and by light aeroplane.

Although the mountains are only 2000m high, they dominate the distribution of lift.

Techniques used in soaring the European Alps are appropriate for Hokkaido. Already, a DG400 has soared a triangle of almost 500km from Takikawa.

As an instructor, Marui-san has written a comprehensive training handbook for Japanese glider pilots. This is now in the press.

I expect that his approach will contrast with that of some of the old school of Japanese gliding instructors, who seem to have been concerned much more with discipline than with understanding.

Marui-san is diffident about thrusting himself on to the Australian gliding scene.

Personally, I extend a warm welcome to him. I hope all Australian glider pilots will join me in this.

Marui-san visited Australia often to instruct or compete, and he hosted Australian visitors at Takikawa. Tragically, he died in a mid-air collision in November 1998, while competing in the Australian National Championships at Narromine.

The LAK-12 Re-visited

By Garry Speight

Originally published in Australian Gliding, November 1993

In the February issue of "Australian Gliding". Viv Drew gave her impressions on the LAK-12 which she flew in Sweden.

A LAK-12 is now in Australia and Garry Speight gives his opinion of the type.

I had the opportunity recently to do some cross-country flights in a brand new open class glider a Lithuanian LAK-12 "Lietuva". I thoroughly enjoyed flying it. and my impression is that it is an excellent aircraft.

My experience in open class gliders is very limited, because they have been beyond my price range, either to buy or rent. I have had only a few cross-countries in a Nimbus 2 and some dual in a Janus and a DG500.

The LAK-12 is unique in being a production open-class glider at a price of less than $55,000. That is cheaper than any standard class glider: a pilot looking to win the standard class nationals must spend a great deal more.

Anyone thinking of buying a new glider should consider whether the standard class is the proper choice. For less money you can get a glide ratio of 48:1. which will keep you airborne before the standard class gliders take off and after they have landed.

The LAK-12 is a 20.4m span glider with a two-piece wing, and with the tailplane mounted just above the fuselage. It has a single retractable main wheel and a tail skid. The flaps have six settings, and the ailerons deflect with them.

Integral water ballast tanks in the wings take 190 litres. The maximum wing loading goes right up to 45 kilograms per square metre and a realistic minimum is about 30 kilograms per square metre.

The LAK-12 Re-visited

The construction of the glider seems to be very sound and conventional. Although most stresses are carried by fibreglass and carbon fibre, there is a steel tube assembly carrying the wing mountings, the undercarriage and the main control bell-cranks. The finish is excellent.

In the cockpit I found I was very comfortable. and I was impressed by the visibility. The handle of the control stick is a little high, but the forces are light. The rudder pedals are pivoted at the instep. I mainly kept my heels on the floor rather than in the heel-rests.

The spring-trim for the elevator is on the left of the stick. It is copied from the Jantar and is not a good design. Fortunately it is not needed except when entering and leaving a thermal.

The flap handle, mounted high on the left side of the cockpit, is very convenient and smooth to operate. There are two negative flap detents for high speeds, one for zero flap, two positive flap detents for thermalling and another for the landing.

The airbrake lever is beside the seat below the flap handle. The airbrake doesn't do a great deal, but the landing flap causes a fairly steep approach anyway. The release handle and the rudder pedal adjustment are conveniently placed just ahead of the airbrake handle. The wheel brake lever is on the control stick.

The only control on the right wall of the cockpit is the undercarriage handle. This is mounted on a tube sliding along a rod that is fastened to the wall at the front end. The "up" and "down" locks are worked by the thumb. Frankly, the locks are a bit fiddly. For a new pilot it would pay to put the glider on a dolly and practice cycling the undercarriage up and down to get the hang of it.

The canopy mounting system is the very latest design. Research suggests that most canopies when ejected blow back into the cockpit, where they are likely to injure the pilot, before they fly back and demolish the tail.

The LAK-12 canopy pivots forward in normal use, as on many modern gliders, but the ejection system is different. There is a red "canopy eject" handle on the panel. When this is pulled, a powerful spring throws the front of the canopy up into the airstream. The rear of the canopy remains momentarily held down by the main fastening pins until the airstream lifts the canopy right off. A large lug behind the pilot's head prevents the rear of the canopy from coming down and striking the pilot as it goes.

For normal use, the handles of the rear fastening pins are a bit flimsy. I found that I had to lift and lower the canopy by reaching back over my head to the canopy frame. (I detest people who put greasy finger marks on canopies!) When open, the canopy is held up. not by a gas strut, but by an over centre arm. To unlock the arm one pulls a white handle on the instrument panel. As to the moulding of the canopy itself, the manufacturers do not seem to have achieved the intended shape. Perhaps this will be rectified later.

The LAK-12 comes with a full panel of instruments, including an airspeed indicator in knots and an altimeter in feet. Also included is an electric variometer with speed command. This seems to be modelled on a Borgelt instrument, and works well.

I liked the calibrated zero adjustment for rate of climb in the "Vario" mode, which allowed me to set the vario zero to the MacCready threshold value. By pressing buttons you can change the response rate in steps from 1 to 5 seconds. (I prefer 3 seconds). I found that the sound of the instrument was sometimes hard to hear.

Two interchangeable batteries are supplied, each fitted in a neat box which clips securely in place. One fits in the nose, where it provides permanent ballast. The other fits in a compartment over the wheel. The batteries supplied each have ten wet cells making up twelve volts. If necessary the boxes will also take the gel cells that are commonly used in Australia.

Flying the glider is straight-forward. Control response is very good, in fact the rate of roll is like that of a standard class glider. Other pilots have also noted how easy this glider is to manoeuvre in comparison with similar aircraft, such as the Nimbus 2 and the ASWI7. It is particularly remarkable since the wings are very like those of the Nimbus 2.

I flew the glider empty and with full water. With full water it seemed to thermal best at about 50 knots and 45 degrees of bank. That was in small rough winter thermals.

The glider provides luxury gliding at low cost. If such low-cost open-class gliders remain available there could well be a drift away from the standard class and the 15 metre class. Why not go for the best glide ratio per dollar?

I flew the LAK-12 during one of several visits to Waikerie, South Australia, to train young Japanese pilots.

Thermals That Rotate, Part 1

By Garry Speight

Originally published in Soaring Australia, May 2006

Many thermals rotate, and they may be the strongest of the day. You can soar better if you learn to work them. Circling against the rotation is a dream; circling with it, a nightmare!

Part 1: Do Thermals Rotate?

Soaring in thermals

A child, watching an eagle getting higher in the sky as it circles without flapping, may think that the bird is cleverly following a narrow current of air that twists upwards like a corkscrew. Glider pilots know the bird is soaring in a large mass of rising warm air, called a thermal.

A thermal may be more than 100m across, and the air in it mainly goes straight upwards, not twisting like a corkscrew. Sometimes the top of the thermal forms a cumulus cloud that shows something of its size and shape.

The eagle circles simply to stay inside the thermal. With wings outstretched, the eagle, like a glider, cannot stop still in the air, or even fly below a certain airspeed: the stalling speed. Flying a slow circle is the best way to climb using the lift of the thermal. Often the air rises several metres per second. Since soaring birds and gliders sink at only about one metre per second, these thermals can lift them up. Usually, birds and gliders climb just as well whether they circle to the left or to the right.

That is not to say that the air in the thermal never goes round and round as the child may have thought. Some thermals rotate.

The case against thermal rotation

Many pilots believe that thermals do not rotate, or think the subject not worth worrying about. They have never noticed anything that suggests enough rotation to affect thermal soaring. I believe this is because the effects of thermal rotation on a glider are so puzzling the pilot may take years to guess their true cause.

People say that they can’t believe thermals rotate because they don’t see clouds rotating. Clouds do rotate. Time-lapse films often show this, and you can see it by watching the first wisps of cumulus as they form in the morning[1].

There may also be a lot more rotation in the middle of a big cumulus than shows in the almost-dead air of the billowy cloud surface. Since the bottom of the cloud is just a flat grey mist, the thermal could be rotating as it goes into the cloud without leaving any sign.

In any case, the rotation is almost too slow to notice. A speed of just one circle per minute would strongly affect a glider.

Tornadoes, willy-willies and cyclones

Both tornadoes, and the larger sizes of willy-willy (or dust devil), are rotating masses of air that are like thermals. They are roughly circular in plan. As in a thermal, the most active part, or core, is around 30 to 80m in radius. They all have low air pressure and density.

Air flows in towards a place where the pressure is low. On a perfectly smooth ground surface the air might flow exactly towards the centre but, in reality, it is likely to twist a little one way or the other. Any slight tendency for the air mass to twist becomes a much faster rotation as it gets nearer to the centre.

On the earth’s surface, the rotation of air (or water) tends to be cyclonic. Cyclonic rotation is different each side of the equator. At places south of the equator, the rotation is clockwise as seen from above. This is because the south side of the air mass is closer to the earth’s axis than the north side is, so it travels eastwards with the earth at a slower speed. Cyclones, hurricanes, and typhoons that are hundreds of kilometres across always rotate cyclonically. Smaller masses of rotating air (or bathwater!) do not.

Experts think that 80% to 95% of tornadoes in the USA rotate cyclonically[2]. Perhaps not so many rotating thermals are cyclonic[3]. In his study of 375 "Sand Devils" in Egypt in 1932, WD Flower found that only 53% of them were cyclonic. On the other hand, Fred Hoinville, in his book "Halfway to Heaven", observed that, of 26 Australian willy-willies, "Twenty-four rotated clockwise; two rotated anti-clockwise." That is, over 90% were cyclonic.

How many thermals rotate?

Even if there were more data, the question "How many thermals rotate?" would be hard to answer. A thermal that rotates very slowly is just like one that does not rotate at all.

I think that a lot of Australian summer thermals, perhaps 5% or 10%, rotate fast enough to affect soaring in gliders.

One glider pilot, HV Senn, did experiments in Florida to measure thermal rotation. He found it hard to do, as he described in "Do Thermals Rotate" in "Soaring", June 1988, pages 42 to 45. Finally, he threw crumpled sheets of newspaper out of an open-cockpit glider as he flew across a thermal marked by circling gliders. He tracked the sheets of paper and noted the movement using a tape recorder.

He wrote: "Do thermals rotate? You bet they do!" Of 30 successful drops, Senn found at least half showed clear thermal rotation: 10 rotated cyclonically, and five anti-cyclonically. The speed of rotation, at a 50m radius, was up to four knots.

Soaring in thermals that rotate

I have often soared in thermals that seemed to be rotating. When soaring was difficult (and I had the thermal to myself), I reversed the turn to see if the thermal became easier to work. Sometimes it was just as difficult, but sometimes it was very much easier!

I started to notice the differences between thermalling in the two directions in rotating thermals. Other pilots have noticed some of these differences.

Here is my list of effects of flying with the rotation and against it.

Flying with the rotation

- The average rate of climb was much lower than in the strongest surges.
- The air was very rough.
- I had to hold the nose of the glider low to keep good control.
- Keeping the nose steady on the horizon did not give a steady airspeed.
- The core of the thermal seemed to be small; I could stay in it only with a very steep angle of bank, if at all.
- Once found, the core was easy to lose, and seemed to move around.

Flying against the rotation

- The average rate of climb was almost as high as in the strongest surges.
- The air was very smooth.
- I could hold the nose of the glider high while keeping good control.
- The airspeed stayed steady and the nose of the glider stayed at the right height without my moving the stick.
- The core of the thermal seemed to be large; I could easily stay in it with a moderate angle of bank.
- The core seemed to stay in one place; centring called for so few control movements, the glider almost flew itself.

What causes these effects?

All of these effects follow from the movement of the air in a rotating thermal, and the response of the glider to the air movement. Parts 2 and 3 of this article explain how and why.

Technical notes

1. The late Ann Welch (writing as AC Douglas) published a sequence of photos (Figure 27a-d) of

a rotating thin cumulus in 1943 in her book "Cloud Reading for Pilots" (London, John Murray).

2. See this web page: [www-das.uwyo.edu/-geerts/cwx/notes/chap07/tornado_form.html] for a discussion of tornado rotation. Cyclonic tornadoes do not rotate cyclonically as a direct result of the earth's rotation (the Coriolis effect). They are spawned by supercell thunderstorms that are themselves mesocyclones. Even the mesocyclones are not driven by Coriolis, but seem to be accidental features, those with cyclonic rotation being maintained by wind shear. Similarly, any tendency for thermals to rotate cyclonically is only remotely related to Coriolis.

The wind shear near the ground contains plenty of vorticity, mainly horizontal. Some of it gets stood up on end in willy-willies and rotating thermals. It is not yet clear whether the process would tend towards cyclonic rotation.

3. AG Williams and JM Hacker ("Inside Thermals", Technical Soaring, 1992, 16(2), 57-64) analysed the structure of many thermals identified from instrumented traverses over Eyre Peninsula, South Australia. Thermals sampled at a level just over half way up the convective layer showed, on the average, a cyclonic rotation. In their opinion, this result was "produced by averaging together many non-rotating thermals with a small number of strongly rotating thermals".

A major gaggle, hopefully in an anti- clockwise thermal

Thermals That Rotate, Part 2

By Garry Speight

Originally published in Soaring Australia, June 2006

Many thermals rotate, and they may be the strongest of the day. You can soar better if you learn to work them. Circling against the rotation is a dream; circling with it. A nightmare!

Part 2: What they are like

Flight In Rotating Air

The glider flies because of its speed through the air. In a thermal, the pilot must keep the airspeed just a few knots above the stall. This airspeed is the same whether flying with or against the thermal rotation, (so long as the air is just as smooth each way). The ground speed is not the same: the ground speed is higher when flying with the rotation than when flying against it.

To keep a turn going, the pilot must bank the glider so part of the lift of the wings pulls the glider towards the centre of the circle. Otherwise, (said Isaac Newton) the glider would fly out of the turn in a straight line. At a chosen speed, a chosen bank angle causes a particular rate of turn.

Is the speed I mention here the same as airspeed? Not if the glider is turning in a rotating thermal. Provided there is no wind, it is the ground speed that decides the rate of turn and the radius of the circle[1].

To see that this is true, think of the path of the shadow of the glider on flat ground on a day with no wind. It is a circle exactly the same as the one the glider makes in the air. It has a certain radius and the distance around the circle is a certain number of metres. The shadow of the glider, travelling at the gliders ground speed (not airspeed), goes around in a given time. From this you can work out the rate of turn, in degrees per second. Thus, rate of turn relates to ground speed rather than airspeed, and so does the radius of turn.

To show how this might affect a pilot flying in a rotating thermal, here is an example.

A pilot circles at 50kt and 45° of bank in a thermal that rotates at 10kt. Flying against the rotation gives a ground speed of 40kt; flying with it gives a ground speed of 60kt.

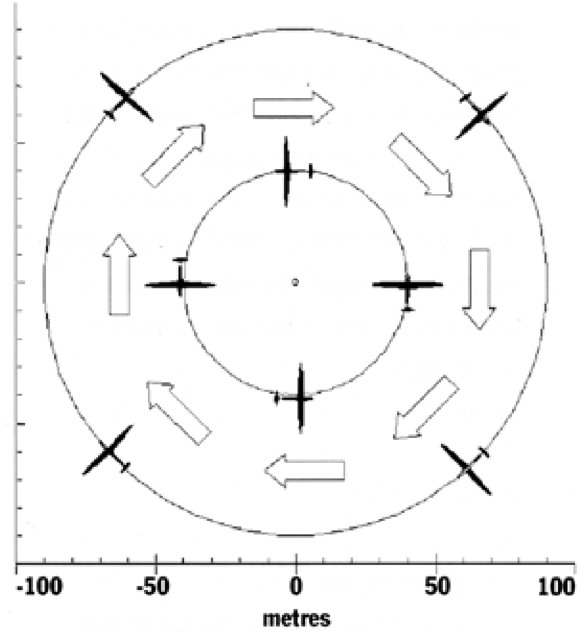


Fig 2.1. Turning radius at 50kt with and against a 10kt thermal rotation

The Technical Note 2 explains how the radius of turn is 40m in the first case and 90m in the second (Figure 2.1).

A thermal rotation of as little as 10kt makes the radius of turn when flying with the rotation more than twice that when flying against it! Added to that, a 90m radius is very large; larger than the radius that Australian pilots normally use for climbing in thermals. The cores of our thermals are seldom wide enough to contain circles that big.

Time Taken To Orbit

The glider takes a certain time to get from a starting point round an orbit back to the starting point. It is not clear whether it will take a longer or shorter time when flying with the rotation rather than against it. Flying with the rotation gives a higher ground speed, but there is more distance to go. In this example, an orbit takes 19 seconds flying with the rotation, and 13 seconds flying against it. The orbit with the rotation takes longer, but not by so much that the pilot will notice[3].

Although skilled pilots notice their rate of turn, and the time taken to get round an orbit, this is little help in deciding the sense of rotation. The circle may be very large or very small without the pilot knowing it.

Winds In A Rotating Thermal

If a thermal rotates, it is like a very weak tornado. Experts have found the pattern of winds in a tornado[4]. I suggest that this pattern also occurs in a rotating thermal, only the winds are not so strong. In Figure 2.2, I have drawn lines to show how much the wind in the rotating thermal has moved the air after certain times. Near the axis the air moves only slowly. Out to the edge of the core it moves faster and faster. Outside the core the air moves slower and slower. Because the air outside the core is moving slower and also has further to go around the circle, it gets left far behind the air in the core.

The flow inside the core is quite different from the flow outside it. The core rotates almost as if it were solid. The air can become calm. Outside the core, each rotating layer of air lags behind the layer nearer the core.

As the layers of air flow past each other, they catch and mix together, curling up to form little willy-willies. The biggest change of speed is in the first few metres outside the core. Here, the air will be very rough.

In a thermal, pilots expect the lift to get less away from the centre, often in a smooth way[5]. In a rotating thermal, every part of the calm core is likely to have the same strong lift (See Figure 2.3). The core will be almost perfectly circular, because the rotation will smooth off any bumps around the edge. In the rough air outside the core there will be wild updrafts and downdrafts. The lift will get very weak not far away from the core.

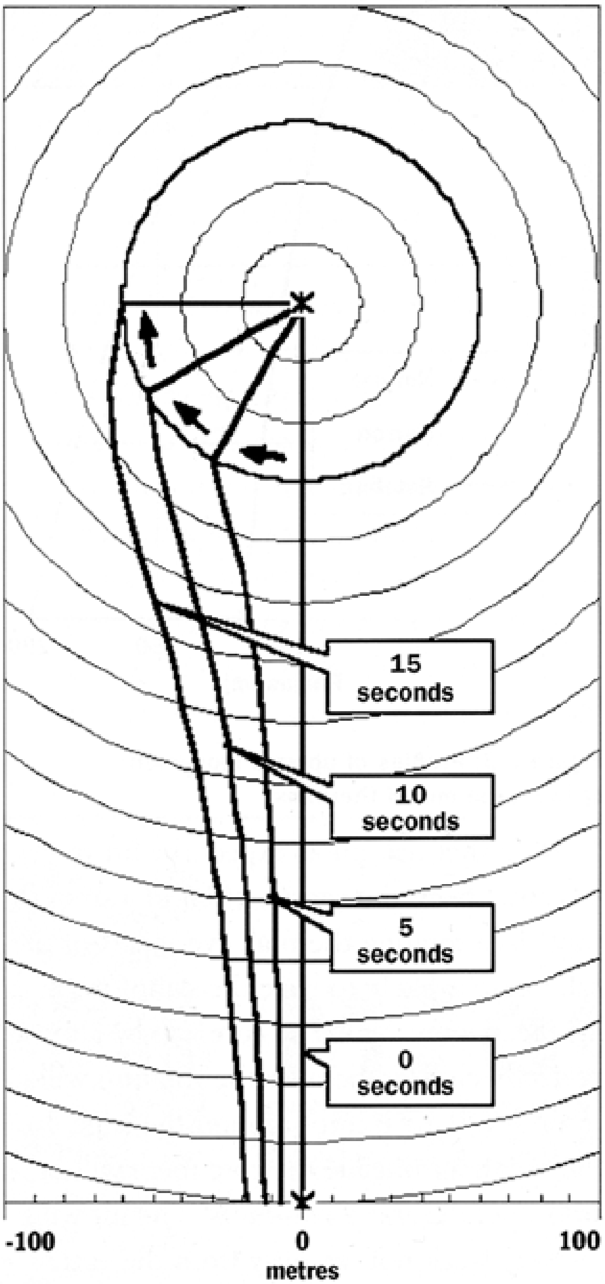


Fig 2.2. Movement of the air around a rotating thermal (as a Rankine vortex)

Features Of Rotating Thermals

In summary, rotating thermals differ from simple thermals in several ways. Clearly, there is a rotating wind that becomes either a headwind or a tailwind for a circling glider. In the core of the thermal, the wind gets faster away from the centre and outside the core it gets slower. The edge of the core is very sharp, and forms a perfect circle. Inside the core the air is smooth, while outside it the air can be very rough.

Thermals That Rotate, Part 2

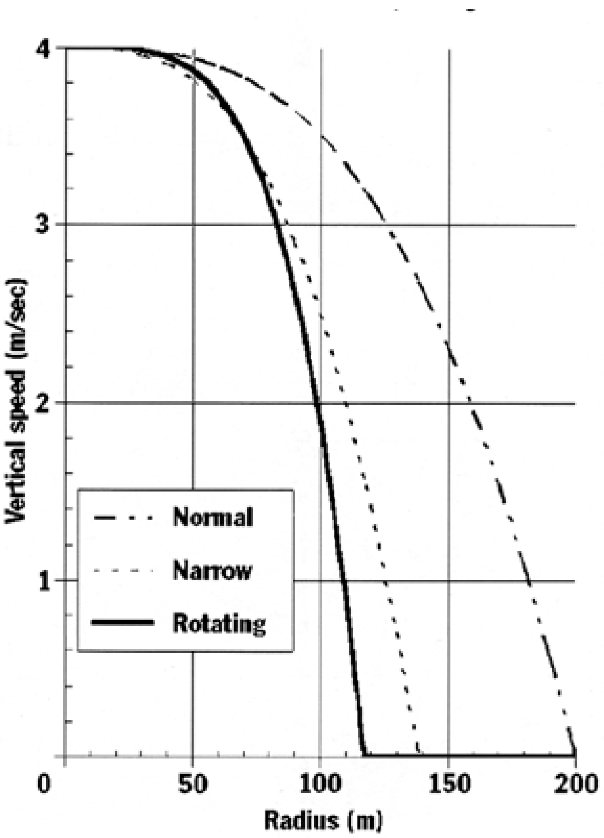


Fig 2.3. Profiles of upward movement of the air in model thermals

In Part 3 of this article I show what happens to the glider in such a thermal.

Technical Notes

1. The pilot must bank the glider to make it fly in a circle. The lift must not only support the glider's weight against the acceleration of gravity, g, but also cause acceleration, f, towards the centre of the circle. The higher the speed, V, and the smaller the radius, R, of the circle, the larger the value of f, and the steeper the bank angle, φ (phi), must be.

The acceleration towards the centre is:
$f= V^2/R$
It is easy to show that:
$\tan\varphi= f/g$
Then:
$\tan\varphi= V^2/gR$
And:
$R = V^2/(g \tan\varphi)$

This shows that the radius of the circle depends on two things the pilot can control: the speed and the bank angle. Unfortunately, "speed" could mean airspeed, or ground-speed, or speed around a circle allowing for the wind. Which is correct?

We can solve this puzzle. Express the acceleration, f, towards the centre of the circle not in terms of speed, but of angular velocity ω (omega). Angular velocity is like rate of turn, but measured in radians per second:
$f = \omega^2 R$
Then:
$\tan\varphi = \omega^2 R/g$
And:
$R = (g \tan\varphi)/\omega^2$

This shows how the radius of turn at a fixed bank angle depends on the angular velocity.

Angular velocity has only one meaning. It is rotation relative to the universe. Since the earth rotates very slowly (only 15° per hour), it is nearly the same as rotation relative to the surface of the earth. On a calm day, the speed that sets the radius of turn of a glider in a rotating thermal is the ground speed. When there is a wind the velocity over the ground must have the wind vector subtracted.

2. Suppose the glider pilot maintains airspeed of 25m/sec (about 50kt) to keep an adequate margin above the stall. Suppose the part of the thermal the pilot is flying in is rotating at 5m/sec (10kt), and there is no wind. Flying against the rotation gives a ground speed, V, of 20m/sec (40kt); flying with it gives a ground speed of 30m/sec (60kt). Also, suppose that the angle of bank φ is 45°, so that $\tan\varphi = 1$. The value of g is about 10.

Find the radius of turn R by:
$R = V^2/(g \tan\varphi)$

In the case of flying against the rotation, R is 40m; in the case of flying with the rotation, R is 90m.

3. Since the angular velocity in a circle is:
$\omega = V/R$

The time for an orbit, T is:
$T = 2\pi R/V$

Thermals That Rotate, Part 2

Substituting for R:
$T = 2 \pi V/(g \tan \varphi)$

This gives the values in the text.

Note that the orbit time varies with the speed, while the radius of turn varies with the square of the speed.

The pilot could still work the thermal if the headwind were equal to, or greater than, the airspeed. When the headwind equals the airspeed exactly, the ground speed is zero, and the orbit could be said to take forever. In this case, no bank is needed. If the headwind is greater than the airspeed, so that the glider is being blown backwards, it must again be banked towards the thermal axis.

4. The pattern of horizontal winds in a tornado is like a Rankine vortex. The Encyclopaedia Britannica reports that, in 1957, meteorologists observed wind speeds of one tornado near Dallas in detail. The rotational speed of the air was very low near the centre, and increased in proportion to the radius, until it was 67m/sec at 60m, then decreased in inverse proportion to the radius, falling below 10m/sec at 400m from the centre. This pattern of linear increase in rotational velocity with radius, followed by decrease inversely with radius (Figure 2.2) is called a Rankine vortex. Others have seen the same pattern in dust devil rotation. Research that is more recent uses other vortex models, but the Rankine vortex model will do.

5. I once proposed two thermal models, "normal" and "narrow" (Figure 2.3) with the lift falling off according to the cube of the radius ("Rate of Climb in Thermals" by Garry Speight, Australian Gliding Vol. 31, No. 2, February 1982, pp 28-39, 47). "Normal" thermals are easy to work; "narrow" thermals need more care and concentration.

I set up these models to put numbers on the profile of Australian thermals as the sailplane pilot sees them. They reflect my experience better than the usual parabolic (square of the radius) ones do, not to mention the very narrow models proposed by Bruce Carmichael in 1954 ("What Price Performance?" Soaring, 18 (May/June), pp 6-10).

Carmichael's thermals are still cited in textbooks, including "Fundamentals of Sailplane Design" by Fred Thomas (College Park Press, Maryland, 1999). Glider designers use much simpler thermal profiles than those glider pilots fly in. Even the latest ones cited by Thomas, those of K H Horstmann, look like a witch's hat (but someone has fudged the profiles, by rounding off the sharp peak in the diagram. Bernard Eckey has copied this diagram for his article in January's "Soaring Australia"). Witch's hat profiles are "Konovalov Type B" thermals, as discussed by Ian Strachan in Sailplane and Gliding Vol. 25, No, 6 (December 1975), pp 266-271.

In metric units my thermal profile models are:
$V_R = V_{MAX} - R^3.k.10^{-6}$
where
V_R is the vertical velocity of the air at radius R in m/sec
V_{MAX} is the vertical velocity of the air at the thermal axis in m/sec
R is radius from the thermal axis in m
k takes the value 0.5 for a "normal" thermal, and 1.5 for a "narrow" thermal.

Two things are to be understood:

1) negative values of V_R are replaced by zero values;

2) the equations do not allow for a broad zone of more slowly rising air that surrounds the thermal core.

Figure 2.3 shows these model thermals in the case of a central velocity of 4m/sec. They will yield a rate of climb of about 2.5m/sec (5kt).

I believe the lift in a typical rotating thermal is like the "narrow" thermal model, but with a broader zone of nearly constant strong lift near the axis, and a more rapid decrease of lift outside the core. This is better matched by a fourth power curve rather than a cubic:

Thermals That Rotate, Part 2

$V_R = V_{MAX} - R^4.k.10^{-8}$ where k takes the value 2.1.

Figure 2.3 includes this curve.

Such a fourth power profile (not unlike a top-hat) is like the "Konovalov Type A" thermal. Helmut Reichmann, in "Cross-Country Soaring" (Thomson Publications, Santa Monica, 1978, p 92) notes that this type of thermal profile occurred when there was strong surface instability, and that turbulence was greater at the edges than in the centre. One would expect both in the case of rotating thermals. Perhaps the Konovalov Type A thermal profile results from thermal rotation.

Thermals That Rotate, Part 3

By Garry Speight

Originally published in Soaring Australia, July 2006

Many thermals rotate, and they may be the strongest of the day. You can soar better if you learn to work them. Circling against the rotation is a dream; circling with it, a nightmare!

Part 3: How the glider behaves

Symptoms Of Thermal Rotation

In Part 1 I argued that there are a lot of rotating thermals about, and I listed things I had noticed when flying in them:

Flying with the rotation

- The average rate of climb was much lower than in the strongest surges.
- The air was very rough.
- I had to hold the nose of the glider low to keep good control.
- Keeping the nose steady on the horizon did not give a steady airspeed.
- The core of the thermal seemed to be small; I could stay in it only with a very steep angle of bank, if at all.
- Once found, the core was easy to lose, and seemed to move around.

Flying against the rotation

- The average rate of climb was almost as high as in the strongest surges.
- The air was very smooth.
- I could hold the nose of the glider high while keeping good control.
- The airspeed stayed steady and the nose of the glider stayed at the right height without my moving the stick.
- The core of the thermal seemed to be large; I could easily stay in it with a moderate angle of bank.
- The core seemed to stay in one place; centring called for so few control movements, the glider almost flew itself.

Each of these things follows from the features of rotating thermals I described in Part 2.

Why The Glider Behaves As It Does

The size of the circle

Some of the effects of flying with the wind in a rotating thermal happen simply because the circle at a chosen bank angle is so large.

As shown by the larger circle in Figure 3.1, the glider may stay outside the core, where there is much weaker lift and rough air (shown by hooked arrows). To keep control the pilot must not stall in tail-wind gusts. This calls for a higher airspeed, making the circle even larger. The rough air also causes more drag on the wing at low speed. (See Note 1.) The pilot must lower the nose of the glider and fly faster.

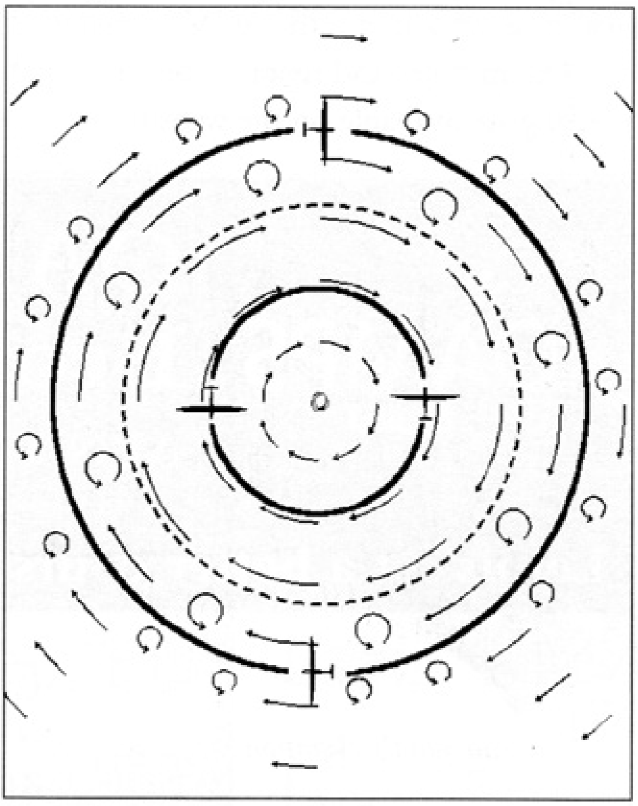


Fig 3.1. The wind pattern in a rotating thermal (shown by arrows), and its effect on a glider flying with and against the rotation. The dashed line is the edge of the thermal core

When flying against the wind, shown by the smaller circle in Figure 3.1, the glider is likely to be within the smooth air of the thermal core all the time. The pilot can raise the nose and fly slowly, getting the best out of the glider.

The size of the glider's circle explains differences in rate of climb, air roughness, and the height of the nose of the glider.

As for the thermal core seeming to be bigger or smaller, it is not the core that is different, but the gliders circle. The pilot can't know how big the circle is.

Stable and unstable orbits

Something else makes the thermal change from well-behaved to spiteful when the pilot circles the wrong way.

The pattern of winds in a rotating thermal affects the path of the glider, to make its orbits either stable or unstable.

- Stable orbits are circles centred on the thermal axis. The glider flies at a steady speed.
- Unstable orbits are oval, strangely-shaped curves that swing towards and away from the thermal axis. The glider flies at an unsteady speed.

In a word, the glider is very easy to control when flown against the thermal rotation, because its orbits become stable. It is very hard to control when flown with the rotation, because its orbits become unstable.

If flying against the rotation within the core of the thermal (see Figure 3.2), the pilot meets a headwind that gets stronger away from the thermal axis. In this case, the rotating thermal tends to make the glider fly in a circle centred on the axis. Suppose the glider is moving slightly away from the axis, as shown on the left in Figure 3.2. It meets a stronger headwind, which gives a higher airspeed. The pilot, to slow down, puts a little back pressure on the stick. This moves the glider back in towards the correct circle. In the same way, any chance movement towards the thermal axis (on the right in Figure 3.2) will give a lower airspeed. The pilot, to speed up, puts forward pressure on the stick. Again, this will return the glider towards the correct circle. (See Note 2)

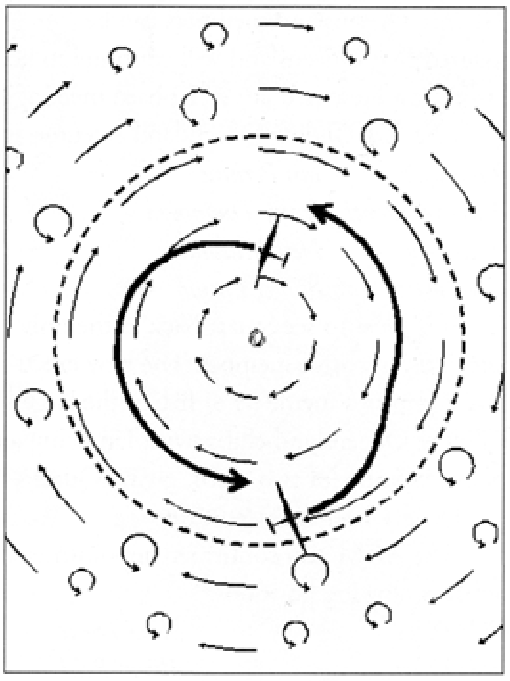


Fig 3.2. Self-centring while flying against the rotation in the core of a thermal

It may happen that, while circling against the thermal rotation, the glider is flying outside the thermal core (see Figure 3.3). Perhaps the pilot is using too little bank, or has not yet found the core. Outside the core the headwind gets weaker away from the axis. Now, if the glider is moving slightly away from the thermal axis (Figure 3.3), it

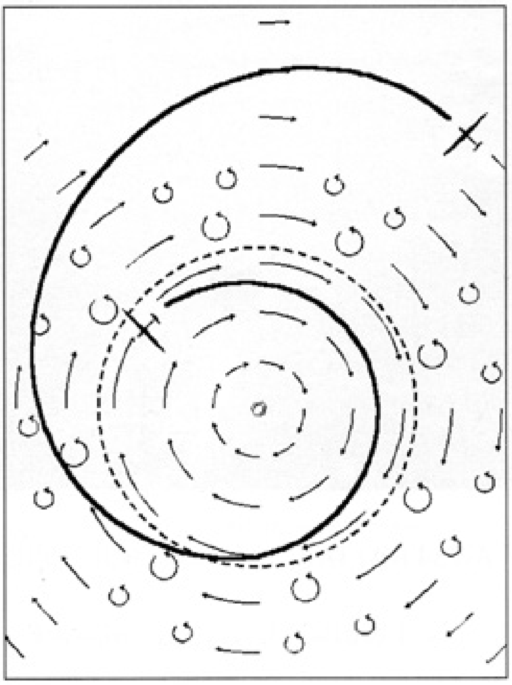


Fig 3.3. A thermal flown against the rotation. An unstable orbit outside the core soon becomes a small stable orbit inside the core

Thermals That Rotate, Part 3

meets a weaker headwind. The airspeed falls, the pilot eases the stick forward, and the glider moves even further away from the thermal axis. This orbit is unstable. Happily, on the other side of the same unstable orbit (on the left), the glider moves towards the thermal axis. Here it meets a stronger headwind. It will gain airspeed, and the pilot, pulling the stick back, will bring it even closer to the thermal axis. It is likely to enter the thermal core. There, the glider will fly at a constant, small radius, and stay inside the core. After only one unstable orbit, the orbits have become stable.

A pilot flying in a tailwind by circling with the thermal rotation may have a wild ride! Because the ground speed is high, making the circle large, the glider will fly mainly in the rough air outside the thermal core. At first the glider's circle, in a tailwind that gets less away from the thermal axis, tends to centre on the axis. This happens in the same way that its circle inside the core tends to centre on the axis when turning against the rotation. These first orbits, flown with the rotation but outside the core, are stable. By chance, every now and then, the glider may enter the strong smooth lift of the core. The pilot will try hard to make the circle smaller, to spend more time in the core.

The orbit is unstable in the core (see Figure 3.4). The glider will not keep flying at the same radius from the thermal axis. The gliders path curves towards the thermal axis, slowly at first. As the tailwind gets less, the airspeed rises and the pilot pulls the nose up. With ground speed falling, the glider is quickly sucked in close to the axis. As it starts to move away again, with the tailwind getting stronger, the glider is thrown right out of the core. By that time it will have a high ground speed, or a low airspeed, or both. On each pass through the core, the pilot has a choice: try to hold the airspeed steady by raising and lowering the nose, or try to hold the nose steady on the horizon and let the airspeed vary. Neither choice will do much good. The pilot is barely in control.

The glider may pass through the core in this way many times without ever getting a full circle in it (Figure 3.5). The radius of turn is too big.

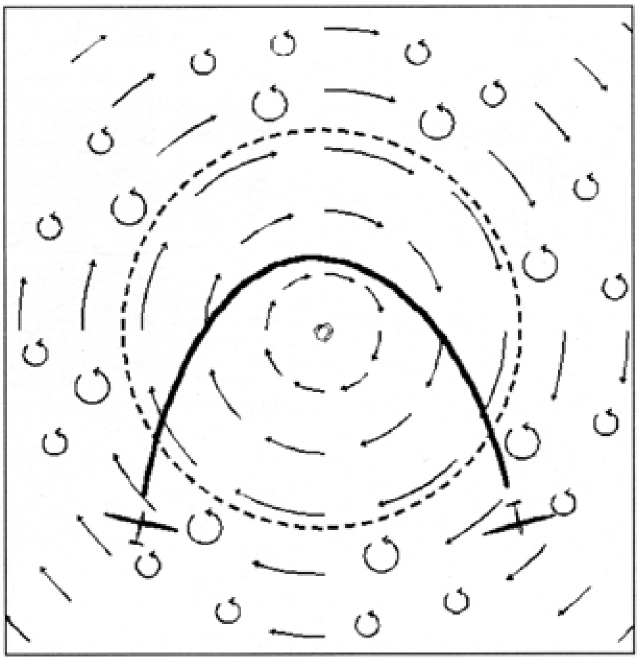


Fig 3.4. An unstable pass through the core of a thermal flown with the rotation

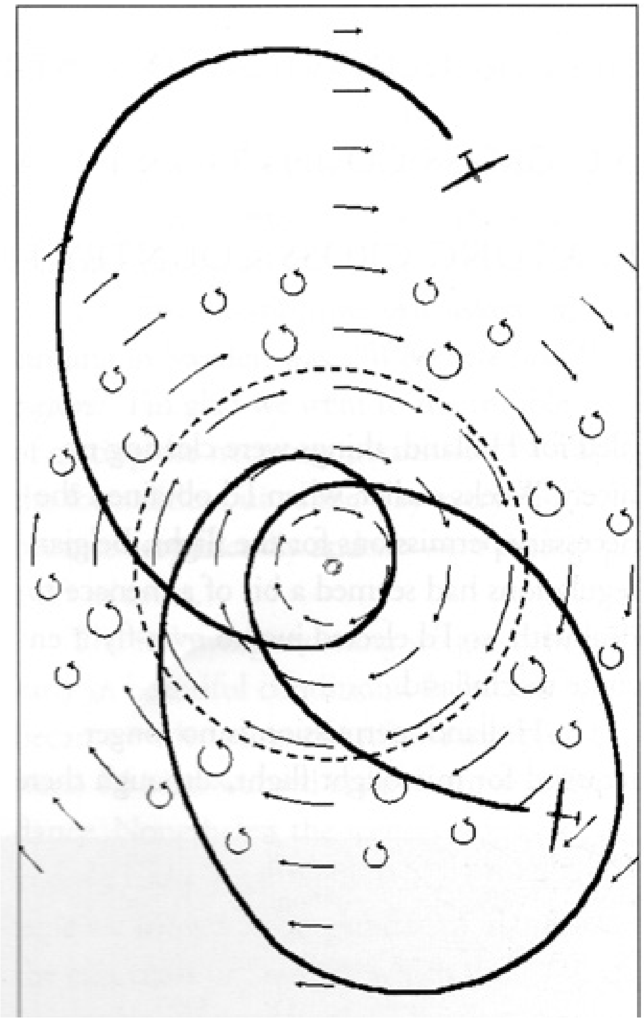


Fig 3.5. Unstable orbits in and out of the core of a thermal flown with the rotation

Thermals That Rotate, Part 3

Thus, the way the pattern of rotating winds changes the path of the glider explains the remaining effects of thermal rotation. Flying with the rotation, it is very hard to control the airspeed, and a tiny thermal core seems to jump to a different place on each orbit. Flying against the rotation, the airspeed is steady, and the glider stays in the core by itself.

In a few words:

A thermal that rotates like a very weak tornado will make a glider behave in the ways I have described. Other pilots have also noticed the glider behaving in these ways. The strongest and most perfecdy circular thermals may often rotate like that. They will give a great rate of climb, and be very easy to use, but only when you circle against the rotation!

What To Do About It

The figures in this part of my article show the glider at the mercy of rotating thermals. The pilot keeps circling in the usual way, blind to what is going on. If circling against the rotation, the pilot thinks the thermal is big and smooth. If circling with the rotation, nothing goes right.

In Part 4 I will show how to use rotating thermals.

Technical Notes

1. Gerhard Waibel reported that glider pilots find lower glider performance in turbulent thermals. His report stimulated a paper by Fabio P. Bertoletti (2001):"Effect of atmospheric turbulence on a laminar boundary layer" (Technical Soaring 25(2), pp154-159). Bertoletti says that turbulence of a few cycles per second (felt as "bumps") causes early transition from laminar to turbulent flow within the boundary layer on the glider wing. Such turbulence makes "streaks" run back along the chord. In one streak, the boundary layer is thinner and faster: in the next it is thicker and slower.

2. I am not sure whether a glider, by its design, will self-centre in such a case even without pilot action.

A Lake Keepit April afternoon sky

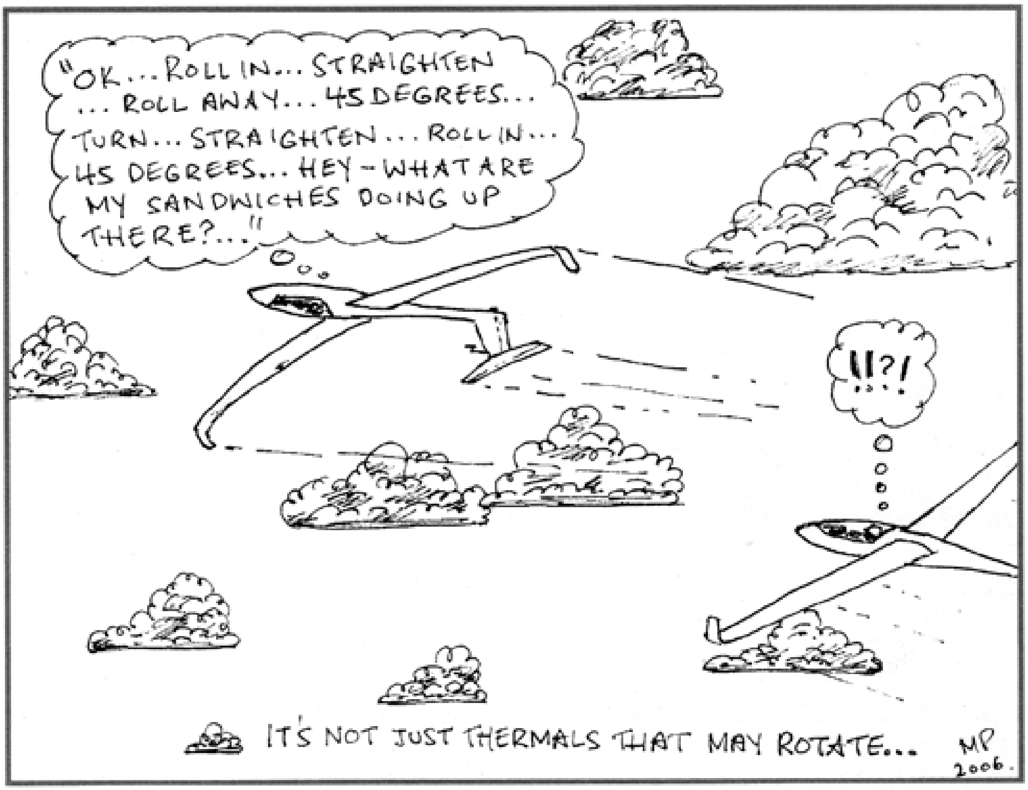
Thermals That Rotate, Part 4

By Garry Speight

Originally published in Soaring Australia, September 2006

Many thermals rotate, and they may be the strongest of the day. You can soar better if you learn to work them, circling against the rotation is a dream; circling with it, a nightmare!

Part 4: How to Soar in Them



The Story So Far

When thermals rotate, they are like very weak tornadoes. This pattern of winds makes the orbits of a soaring glider small and stable when the pilot circles against the thermal rotation, and large and unstable when the pilot circles with the thermal rotation. Clues that the pilot is circling with the rotation include: poor rate of climb, very rough air, a core that seems very small and seems to jump around, having to fly with the nose of the glider pointing down, and surges in airspeed. Circling against the rotation gives a higher rate of climb in a smooth core that seems large, and the glider stays in the core by itself at a steady airspeed, with its nose pointing up.

What To Look For

Take every chance to look for signs of rotating air flow. Watch willy-willies from the ground. As it is easy to misread their direction of rotation, I always check if they could be rotating the opposite way to that which I first thought. Two or more windsocks, or one windsock near a willy-willy, can also show rotating flow.

A big willy-willy, seen from the air, usually has an obvious direction of rotation.

It is clear which way one should circle to fly against it. I find it helpful to say my choice aloud, for example: "I must circle to the right!" It may take some time to get there, and most of the dust will have gone.

If there are four or five small willy-willies, things are not simple. Small willy-willies, like planetary gear wheels, may surround a larger one or a thermal that rotates the other way. Many small willy-willies do not rise above the hot layer of air on the ground surface (the super-adiabatic layer).

When I see rotation in a thin cloud above me, I find this trick useful. I trace out the rotation of the cloud by making circles in the air with my finger. Still making circles, I lower my hand until I can look down on it. Then I decide to circle the opposite way.

Even without visible signs, you can use your mind's eye. For example, if the corner of a forest seems a likely thermal trigger point, the wind must curl around the corner. Work out the direction of rotation, and plan to circle against it.

Learn from the soaring birds! Eagles, ibises and pelicans have had millions of years of practice. If a thermal is rotating, they will surely circle against the rotation. Birds of prey, forever scanning the ground, hunt better if they fly in calm air in small circles at the slowest ground speed. If you meet an angry eagle head on, you may think she is defending her territory. That may not be the problem. She could be furious that you are so rude, ignorant and stupid as to circle the wrong way!

Techniques

Caution

These techniques are for skilled glider pilots. Trying to master rotating thermals without enough skill will bring danger and little gain.

I have listed the nasty effects of flying with the thermal rotation. Reading this, some pilots may joke "...but all my thermals are like that!" If this is no joke for you, you must first master thermal skills. In thermals, you should fly almost perfect circles. Airspeed should not change at all, and angle of bank should not change except on purpose: to shift the circle to a new centre (see Note 1).

I am speaking of three levels of learning. The first is to make perfect circles by careful flying. The second is to circle in the thermal core, never leaving it for more than a few seconds. The third is to make sense of other things, like thermal rotation. All are based on:

- looking at the horizon and the yaw string above it,
- listening to the wind and the audio-vario,
- feeling the way the glider moves, and
- (now and then) reading what the instruments say.

Pilots who have techniques for coping with rotating thermals generally have more than 1,000 hours cross-country experience.

Variometers

Some pilots are slow to learn thermal skills because of faults in their variometer systems. Variometers are very well made, but not all are well installed and few are well maintained. Work on your variometer system until there are no leaks, no false readings, and no stick lift. Adjust the response rate to match the way you fly; instruments can respond to pulses of lift that are too small to use.

Habits of Circling

Pilots form a habit of circling one way rather than the other. Because we turn right after aerotow release, many pilots circle to the right much more often than to the left. Contest organisers add to this with a safety rule that thermalling in the start point area must be to the right.

When they should circle the other way, some pilots fly badly or do not circle at all.

If you are serious about your skills, practice the direction of turn that you like less. Since our rotating thermals are more likely to rotate to the right, a habit of circling to the right is worse for you. On the other hand, some thermals rotate to the left. Do not join every thermal in a circle to the left just to make the odds a little better.

Thermals That Rotate, Part 4

Thermal Entry And Thermal Rotation

If a thermal is rotating, the pilot's best efforts to centre it may result in circling the wrong way, that is: with the rotation.

When one wing goes up, it is generally best to put it down, to begin a turn towards it. This action assumes that the glider is meeting the edge of the thermal at an angle, and the thermal core is on the side of the wing that went up.

The wing may have gone up not due to rising air, but due to a crosswind gust from that side. A higher airspeed on that wing (and the glider's dihedral angle) causes more lift.

If this crosswind is part of the flow in a rotating thermal, the turning glider is now meeting a headwind (see Figure 4.1), and the airspeed will increase. This allows the pilot to pull back and climb well for a few seconds. However, the centre of the turn is well outside the thermal core; the glider will soon go back into rough, sinking air, and the airspeed will fall again.

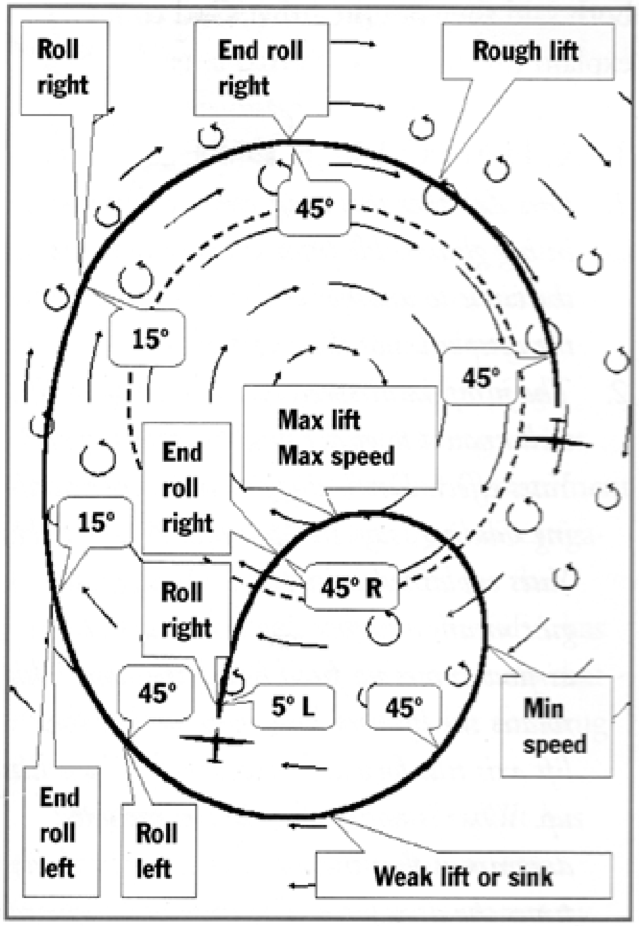


Fig 4.1. Turning towards a lifted wing in a rotating thermal. There is a sudden surge in lift and airspeed. Normal re-centring gives a bad result: a large circle in the direction of rotation

The standard thermal centring action is to note the point (Figure 4.1) where the sink is worst, and decide not to fly through it again. Keep the glider well banked for several seconds, then roll out (along the left edge of the figure) to move the circle away from the worst point. Then roll in to the new circle. This will take the glider back to the core, but in a large circle that goes with the rotation of the thermal.

When the glider first meets the edge of the core of the rotating thermal (Figure 4.1), its higher airspeed comes not only from the stronger headwind, but also from the upward gust of lift, which makes the glider fly faster (see Note 2). If the thermal is both strong and strongly rotating, you get a great burst of speed that you can use for a very high rate of climb. Then, as the glider leaves the core, its airspeed suddenly falls off - even below stalling speed - and drops out of control. The glider has 'bounced' off the thermal. The pilot feels like a squash ball hitting a wall. I have had that feeling! Not thinking that thermal rotation could be the cause, I have even come back to bounce off the wall again and again!

How To Detect Rotation At Once:

A) If Airspeed Rises

When you hit a thermal suddenly and hard with the airspeed rising, as above, this is a strong clue that the thermal is rotating. You are flying into the wind, but not circling the right way. Roll over the other way at once (Figure 4.2). This roll will take at least four seconds, even in a short-winged glider. However, because your ground speed is low, you will not go very far from the thermal core.

Thermals That Rotate, Part 4

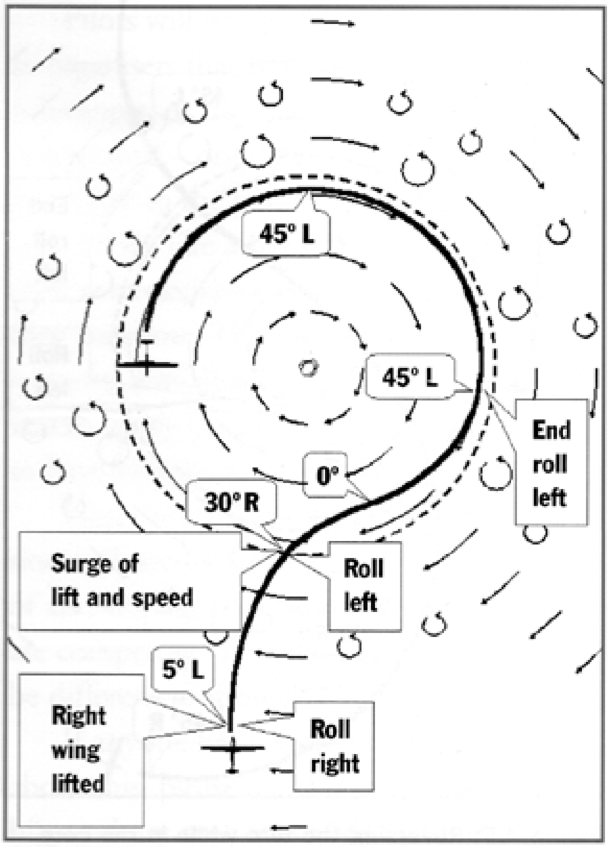


Fig 4.2. Reversing the turn on entry to a rotating thermal, as a response to a big surge in both lift and airspeed

I have seen top-ranking pilots, after turning some 60 degrees one way and gaining height, then circle the other way - as in Figure 4.2. One reason for doing this (without thinking about thermal rotation) would be that to continue the circle would carry the glider from a point with strong lift back into air with no lift a few moments earlier. The air ahead is likely to be better.

British National coach John Williamson taught that the manoeuvre in Figure 4.2 is quite normal. It happens when a pilot, using no variometer but only his feelings of 'lift' and tilt' has met a thermal square-on (see Note 3).

The pilot who changes direction like this must keep a sharp lookout. The danger may be a little less than it seems: A following pilot who is a 'leech' will not be shaken off; others may be far enough away to wait until the leader has clearly chosen a circling direction.

B) If Airspeed Falls

The airspeed, as you bank in to strong lift, may fall sharply instead of rising. This also could be due to thermal rotation. It suggests (see Figure 4.3) that your circle is in the correct sense (opposite to the rotation), but is mainly outside the thermal. As a result, there is a tailwind during your time in the core. The standard centring action will work well. The turn radius will be large during the first entry to the thermal, due to the tailwind. It will be smaller in the second circle which (with luck) could be all inside the core.

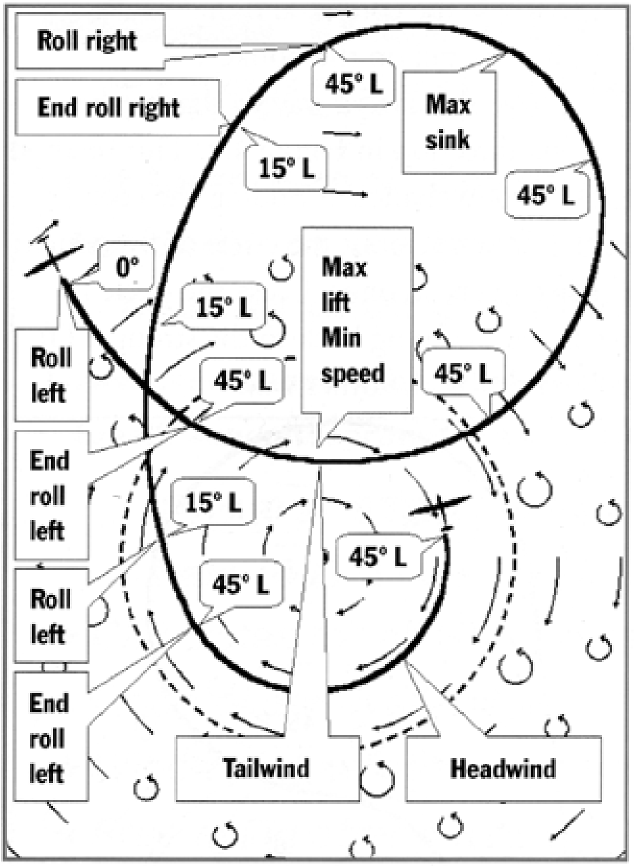


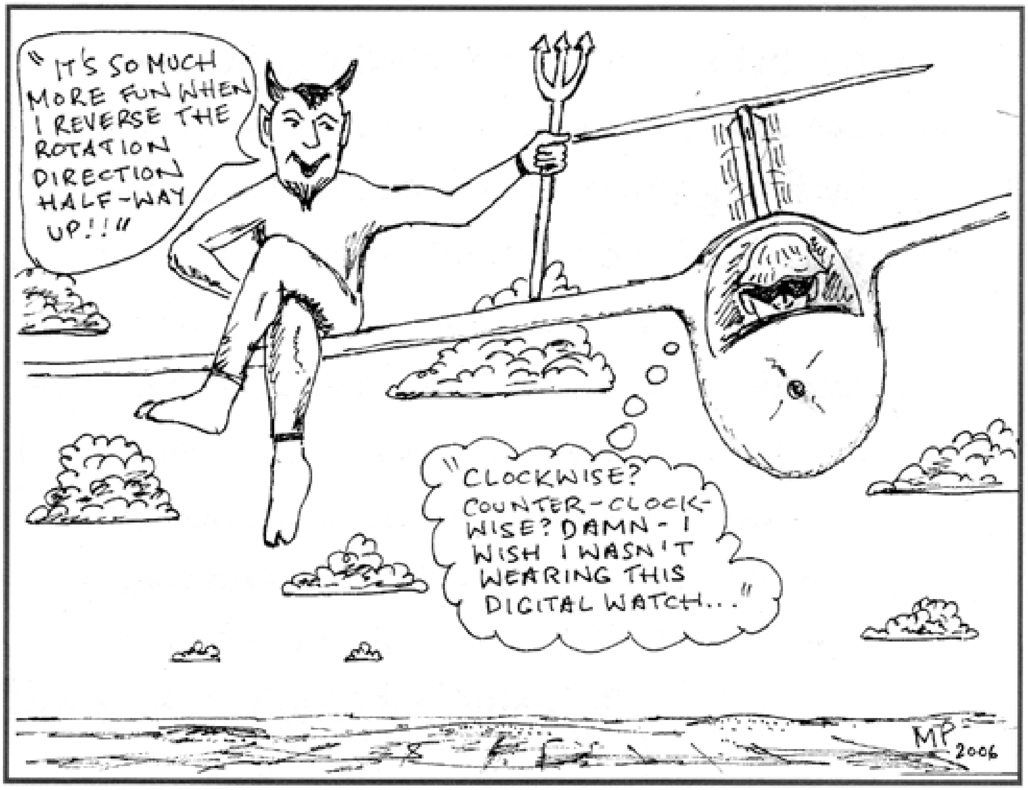
Fig 4.3. Entering a rotating thermal, with airspeed dropping because of a tail wind. Normal re-centring gives a good result: a small circle against the rotation

Reversing The Circle

When you have done two or three circles, various features of the thermal will appear.

If these suggest that you are circling with the thermal rotation, you should do something!

Thermals That Rotate, Part 4



A poor rate of climb, by itself, says: Leave the thermal and look for a better one. Other features favour staying and circling the other way. Count them off:

1. There have been strong surges of lift.
2. The air is very rough.
3. You have to hold the nose low.
4. You can't hold the airspeed steady.
5. The core seems too small.
6. The core seems to jump around.

There are some problems. If other pilots are already circling in the same thermal near the same level, reversing the circle is against the law. Perhaps if you are flying with a friend, you could agree to reverse at the same time. If you think you may not be alone, make a radio call on the gaggle frequency.

It is hard to change direction without losing the thermal. It may take time that could be better spent moving on. You must guess where the core is, and that is like pinning the tail on the donkey!

I have sketched a way to change the circling direction in Figure 4.4. This method gives a good chance of finding the core again. First open out

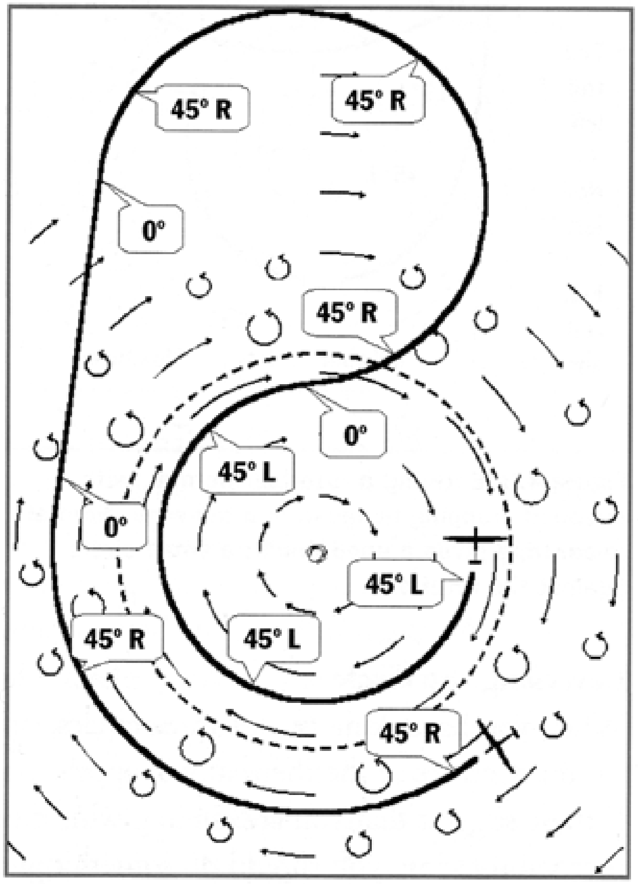


Fig 4.4. Reversing the turn after flying away and coming back to the core

the circle to fly straight for five or six seconds. Close the circle in again and, coming back to the stronger lift, roll hard over the other way.

During the next circle, note the point of weakest lift or worst sink, and move away from it as usual. Sadly, this circle is often all in sink. Begin a new search for the thermal, and remember not to circle the same way as before!

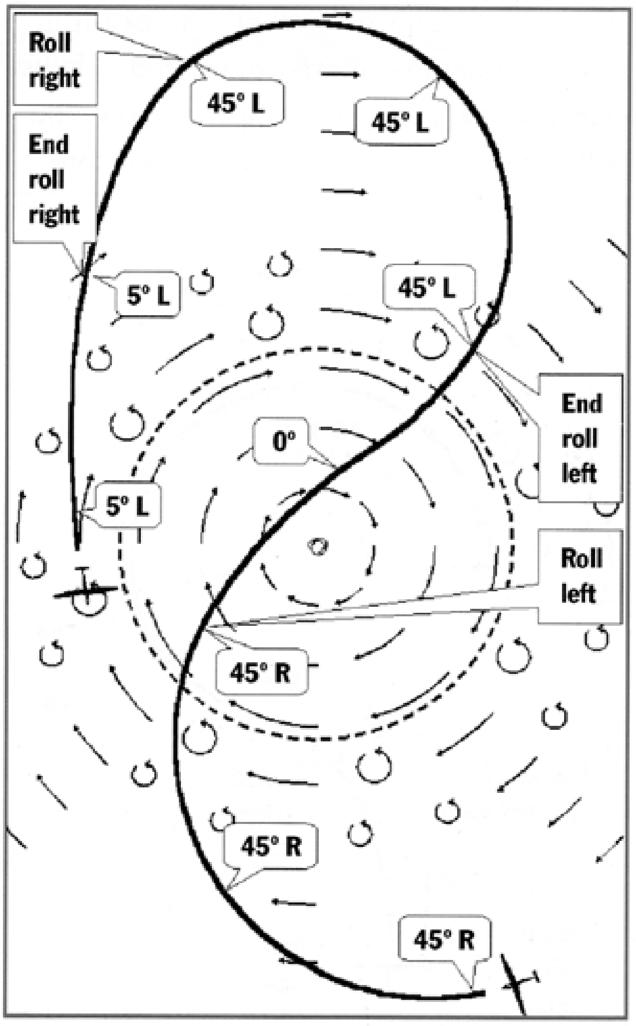


Fig 4.5. Reversing the turn while in the core

Another way is simply to reverse the turn while the lift is strong (Figure 4.5). Due to the long distance travelled while rolling in a tailwind, the next circle is almost bound to be in sink.

Success in reversing the circle will not come without practice.

Making The Best Of It

When circling against the rotation of a thermal, keep your mind on the job, even though the glider seems to fly itself. Your usual bank angle is likely to be too steep. The rotation spreads the highest lift out from the centre to a larger radius. This, as well as the low ground speed, means you need only a gentler bank angle, at which the glider does not sink so much. You can sink even less by flying slower than usual because the air is so calm and the bank angle low.

Seek the bank angle that yields the best rate of climb. It helps to have a simple bank angle guide above the instrument panel, and an audio-vario that can be set to beep only at a high rate of climb (or at a rate that beats the average). The bank angle guide allows you to hold the bank truly steady. The zero-shifted audio-vario tells you clearly when the climb is best.

Another idea is to try to make the circle as large as it can be without flying out of the smooth core. A method used in flying sea breeze or storm fronts (and even in basic aerotow) is to 'bump' the turbulent air. Open out the circle until the outer wing buffets in the turbulent eddies outside the core. Then close the circle in a bit, and keep the angle of bank steady.

Is It Worth Changing Direction?

Changing circling direction may waste time, or even fail; but think what you will gain if you succeed. Rotating thermals, when flown against the rotation, are very easy thermals to soar. They give a higher rate of climb than non-rotating thermals of the same lift strength at the axis. Added to that, the thermals most likely to develop rotation are those that began with a lot of energy. They may be the strongest thermals of the day.

How much you gain depends on the time the glider will be in the thermal. Near cloudbase, it is not worth changing direction. The lower down you start to circle against the thermal rotation, the better. However, lower down there is also more risk. At circuit height over a paddock that looks bad, trying to reverse the turn in a gusty, fitful little thermal can make your heart pump.

Thermal Soaring Sport And Science

Few soaring pilots have spoken or written about rotating thermals. Soaring is both a sport and a science. In sport each pilot tries to gain an advantage. Knowing how to work rotating thermals may be a 'secret weapon' for some racing pilots. If so, I am sabotaging it!

I like to think that soaring pilots are field workers researching turbulence. This is a subject of Satanic difficulty. Physicists Werner Heisenberg and Horace Lamb both said they doubted that God could explain turbulence!

Technical Notes

1. Lars Zehnder uses a different technique in big gliders. He finds it easier to move the circle to another centre by changing the airspeed, not the angle of bank.

2. The jump in airspeed due to a surge of lift, well known to glider and tug pilots, is the Yates effect. Derek Piggott, in 'Understanding Gliding, says in Appendix A how A. H. Yates explained it in 1951. An upward gust means a higher angle of attack: the airflow comes up from below the nose. This rotates the lift and drag axes, so that the lift axis tilts forward, and the drag axis tilts up. What is not so clear in the included diagram is that the lift force is about thirty times the drag force. The increased forward component of the lift tending to pull the glider along can be several times greater than the total drag tending to hold it back. The glider (or aeroplane) accelerates like a drag-racing car. The pilot can feel the push or hear the wind noise, and see the needle rising on the airspeed indicator.

3. John Williamson published these ideas in 'Come Soaring' (Sailplane and Gliding, February/March 1987, pp 4-15). (I thank John Hoye for this item.):

Using a paper plate, slit and fastened with a paper clip, he made a model thermal shaped like a cone. He showed how the pilot who happens to hit the thermal in the middle will not feel any tilting to one side, but only a lift upwards. The pilot must turn one way or the other to stay in the thermal, and will then feel the stronger lift in the thermal core tilting up the raised wing. That wing should be rolled down, and the glider will then circle around the core. In the case of a rotating thermal, the feelings of lift and tilt are in reverse order. The pilot responds to a tilt by banking, then to the lift by reversing the turn.

4. I would like to thank a number of pilots who have discussed rotating thermals with me. I am very grateful to those who have reviewed drafts of this article: Patrick Burke, Graham Holland, Hartmut Lautenschlager, Brian and Carol Marshall, Harry Medlicott, David Shorter, and Jim Stanley. Mitch Preston kindly agreed to do the cartoons.

Letters to the Editors: Rotating Thermals

Although I would have liked to see more discussion of rotating thermals, the topic attracted these seven replies.

From Allan Ash

Originally published in Soaring Australia, July 2006

The article 'Thermals that rotate', by Garry Speight, Soaring Australia, May '06, brought to my mind something that has puzzled me for years.

During 1949 I was a member of the London Gliding Club in Britain and I carried out a number of thermal flights in Grunau Baby and Slingsby Prefect sailplanes. I found that I could circle quite comfortably to the left (anti-clockwise and in the direction of thermal rotation) without any special concentration, but when I circled to the right I found I needed a bit of extra concentration to maintain the correct speed, angle of bank and nose position.

I put this down to the fact that I was, at that time, a relatively inexperienced soaring pilot.

On my return to Australia in 1950 I found that I could now circle quite comfortably to the right (again, in the direction of thermal rotation) but needed a bit of extra care in circling to the left! Any relaxation of this care resulted in fluctuations of airspeed or nose position. The extra care did not result in any great trauma, but it was noticeable.

As a result, whenever I encounter a thermal I now choose to turn to the right, and if this takes me out of the best lift, I simply adjust the circle until I am centred properly. I make left turns in thermals only on rare occasions. Strangely enough, making left turns at other times, such as in the circuit, don't bother me at all.

Do other pilots have this or similar troubles? Is there something wrong with me? Am I perhaps imagining it all? Do pilots from north of the equator, when soaring in Australia, encounter similar experiences?

If it is of any significance, I am normally right-handed, though there are some things that I do left-handed, such as operating my computer mouse. Does any of the above information have any significance on Garry Speight's excellent teaching?

Rotating Thermals

Kingsley Just

Originally published in Soaring Australia, October 2006

In June's Soaring Australia, Garry Speight proposed a theory as to why sometimes pilots report a particular direction of turn in a thermal as being more comfortable than the other. I do not dispute that this phenomena exists, but I think his theory and reasoning is wrong as to why it occurs, I would hate to think that an untested theory is assumed to be correct, and accepted by the gliding community. I was hoping that someone else more concise with arguments would send in a letter, but none have come so far; so I guess I'm it. I'll do my best to outline my arguments in non-mathematical logic that will hopefully be easy to understand. Hopefully this will catalyse a better explanation.

Let's start with a few assumptions: that the glider's angle of bank does not change; that its airspeed remains constant at a safe margin above the stall for the given angle of bank, flaps, weight and atmospheric combination; and, for argument's sake, a 45° bank angle and 50kt airspeed. The tornado-type model of the rotating thermal as described by Garry is also assumed.

Garry's argument seems to fail when he starts to confuse ground speed with airspeed. To achieve a climb, the glider pilot is only concerned with how small his or her turn radius is within a volume of rising air. It is what you can do in that given volume of air that counts. The ground speed is irrelevant, and in fact has no effect on the radius of the turn. Garry states that it is the "ground speed that decides the rate of turn and the radius of the circle." This is wrong; it is the airspeed and angle of bank which dictates the rate of turn. IFR pilots deal with this every day, and adjust speed and bank angle (and therefore rate of turn) to allow for wind effects to make good a track along the ground. For example, a 'Rate 1' turn is 180° in one minute. The IFR pilot knows that with a strong wind, a Rate 1 turn will still take two minutes to fly a 360° orbit.

A turn is achieved by the centring force which is derived by angling the lift force towards the centre of the circle. This lift force is generated by airflow over the wing of the glider. No matter what the ground speed is, extra force cannot suddenly be generated out of the air at a given airspeed and bank angle, in order to make the circle bigger or smaller.

So let's get back to fun flying - that is, of course, gliding. Let's assume we are in heaven, perfectly centred in one of these rotating thermals, and hopefully climbing like a homesick angel. Well also assume three constants: the speed of rotation of the thermal for our circle, our airspeed, and our bank angle. We turn through 360° in one minute in nil wind. For this thought experiment, we have a balloon which is neutrally buoyant. We drop this balloon to mark out where the circle starts in this parcel of air. In one minute we arrive back at the balloon; we have turned a perfect circle in this volume of air, and have traced a perfect circle along the ground.

Now let's rotate this thermal, and fly against its direction of rotation. We are still indicating the same airspeed and angle of bank. We drop this balloon again in the rotating thermal. We arrived back at the balloon, having completed a circle in one minute in this volume of air. But where is the balloon in reference to the ground? Yep - it has moved along the ground. We have in fact only flown part of a circle along the ground in the minute, despite having arrived back at our balloon. As you can see, the radius along the ground is the same.

The opposite occurs if we fly with the rotating air. We drop our balloon and in one minute arrive back at it; but with reference to the ground we have completed a bit more than a full circle. In the given volume of air our airspeed, angle of bank, radius and rate of turn is the same. We still get to the balloon in one minute.

Another way to look at this is to experiment with two sheets of tracing paper and a pen. The first sheet is our thermal. Mark the start, and draw a circle on it. Imagine it takes one minute to draw the circle. Now with the second paper beneath (representing the earth) mark the start of the circle on both pieces of paper by pressing hard with your pen. Both pieces of the paper have marks where we started the turn. Draw the circle, again taking one minute, but rotating the tracing paper (thermal) a bit. The radius of the circle is the same, but you have arrived at a different spot on the earth in the minute it took to draw the circle.

I think I have shown by simple examples that ground speed has nothing to do with either the radius of turn in a rotating thermal or the reason that it seems easier to fly against a rotating thermal. This was a fundamental assumption in Garry's explanation of the phenomenon.

It can be easy to find holes in theories, but it takes courage and a lot of thought to put your ideas out there for people to take shots at. For this I applaud Garry for his work and ideas, and hope he will continue to contemplate the mysteries of gliding. My feeling is that an explanation will be found when we investigate instantaneous effects on airspeed as we fly through different circular wind velocities in thermals in an circular path which is non-centred due to inertia or wing loading - something like continuous wind shear, except in the turning plane. (I hope you followed me on that one.) I would be interested to know if hang gliders experience this phenomenon as much as the heavier sailplanes, as that would be supporting evidence. On the other hand, it might be that it is easier to fly into the wind due to the effect on the glider's stability and performance, enabling the pilot to fly at lower speed for a given angle of bank and to circle tighter. I also wonder how we could test such theories.

This is one reason I love aviation: even in 2006, we still do not fully understand the place we play.

Author's reply:

I am sure physics is on my side. I explained it in my article twice: once in a hand-waving way in the text, and once more rigorously in the Notes... If we get a debate going, I think heavy-weights will come out on my side.

On Kingsley Just's letter

Michael O'Brien

Originally published in Soaring Australia, December 2006

I have just read Kingsley Just's letter (October issue, Soaring Australia), and I am on Garry Speight's side.

Kingsley's talk about rate one turns is just an irrelevance. I doubt IFR pilots are better placed to understand this, flying around inside clouds or in the dark! But any glider pilot who has thermalled down low on a windy day should have worked it out: A steady wind, moving at a constant speed, AND IN A CONSTANT DIRECTION, will not change the duration of the turn for a given speed and a given angle of bank. As long as you just fly by horizon attitude, it is easy to maintain constant speed, attitude, and angle of bank. If you look down, there are confusing visual effects as you seem to go much faster downwind, and much slower into wind. This can be particularly confusing if you are in mountainous terrain, with no clear horizon reference. This is all pretty well known and understood, and was done to death in this magazine many years ago. But it is irrelevant to what Garry's article is about, which is where the wind changes in direction around the circle.

A nice way to test arguments is to take them to extremes, and see if you can break them. If a glider was thermalling at 50kt and 45-degree angle of bank, and pointed into a thermal rotating at 50kt, how long would it take a turn? Think before reading on...

I hope you all worked out this is a trick question. You might have concluded the glider would stay still over one spot. However it would not need any angle of bank to do so, it could just fly straight ahead!

Now the diameter of the circular 'streamline' in which the glider is 'hovering' could really be any number. If it was on the edge of a cyclone, it might be a 100km, say. If you dropped a balloon, it would take a long time to come back to you. However, if it was smaller, let's say the top of a tornado, it would come back faster.

Let's assume the glider is flying along a streamline with a circumference of 1.667nm. How long would the balloon take to come back?

The answer is 1.667nm/50nm per hour = 0.0333 hours, which is two minutes. So according to Kingsley's balloon argument, the glider is doing a rate one turn and it is not even turning!

But really it is the balloon that is doing a rate one turn (in the opposite direction), and it has zero airspeed!

If you want something serious, read the technical notes of Garry's article in the June 2006 issue. They are very clearly and beautifully presented. However, if you prefer the absurd try this one:

A pet shop owner has to deliver a three-tonne load of budgerigars, but only has a one-tonne ute.

If he builds a large lightweight cage, and places a cat in the bottom to make sure the budgies do not land, can he transport these without damaging the springs on his ute?

Advanced questions:

1. Does it make any difference if the cage is totally enclosed, as opposed to made of mesh?
2. What should he say if he is pulled over by a transport inspector?
3. If the budgies all circle in one direction, will it make his steering pull off to one side?

Rotating Thermals I

Hans Gut

Originally published in Soaring Australia, December 2006

When I read the 'Letter to the Editors' of Kingsley Just in the October 2006 edition, I was compelled to analyse the articles of Garry Speight about the subject in more details and respond to it.

Part I: Do thermals rotate?
Pages 28 and 29 in the May 2006

Edition There is no doubt in my mind that some thermals do rotate. In fact I believe that all thermals rotate, except, maybe, the bubbles of rising hot air, which have completely separated from the ground.

It is the same effect as when pulling the plug in the bath tub. The direction of rotation depends on small disturbances when the air leaves the ground.

So I agree completely with Garry's Part 1.

Part 2: What they are like.
Pages I to 3 in the June 2006 edition

When I first read Garrys' article then, I did not go through the trouble of checking all his formulas he used to calculate the effect of the rotating thermal on the turning radius. But it certainly made sense to me. And I have found out since, that by changing the direction of turning in some difficult-to-work thermals that it can make a big difference.

When checking the calculations about the turning radius at 50kt with a banking angle of 45-degrees, I arrived at the same result.

As shown in Figure 2.1 in Garry's article: The turning radius, when circling with the thermal which is rotating with 10kt, is 90m compared to 40m when circling against the rotation. But this is only correct if the rotating speed of the air is the same at 40m radius as it is at 90m radius. But this is not likely being the case, because at a radius of 90m the glider is most probably flying outside the core. So the glider will be circling with a somewhat smaller than 90m radius. However, the principle is correct. Now, back to Kingsley's letter in the October Edition.

He does not believe that the ground speed has any effect on the turning radius in a rotating thermal. He is right and wrong. Because, as Garry explained, the angular velocity determines the turning radius when flying with a fixed airspeed and a fixed bank angle. And the angular velocity of the glider in a rotating thermal happens to be identical to the ground speed on a calm day only. Therefore, the ground speed should probably not have been used at all for the explanation. The angular velocity remains the same whether it happens on a windy or on a calm day.

I'm sure that most people will agree with Garry's article, which is most likely the reason why nobody has responded before Kingsley did.

Rotating Thermals II

Jim Grant

Originally published in Soaring Australia, December 2006

With reference to Kingsley Just's letter in the October edition of Soaring Australia about Garry Speight's theory on rotating thermals in previous editions.

I am not one of the heavyweights that Garry Speight thinks will come out in support of his theories on rotating thermals, but I have a view that may help Kingsley Just focus on the relevance of his arguments to what is happening when flying in a rotating thermal.

Starting with Kingsley's assumptions of constant angle of bank and airspeed, let us also assume the glider is at an ideal distance from the centre of our theoretical thermal and flying into the rotating air.

My view is that the gliders speed around the thermal is its airspeed minus the rotating air speed at its position in the thermal.

To test this view let us increase the thermal rotational speed. In order to remain at the ideal distance we previously had we would have to reduce the angle of bank. Increase it further until the headwind from the thermal equals the glider airspeed and we would not be banked at all. Notice that I have not mentioned groundspeed? Over to the heavy-weights!

Thank you for your articles Garry.

Rotating Thermals

By E Sherwin

Originally published in Soaring Australia, Frbruary 2007

I found the articles by Garry Speight, 'thermals that rotate', most interesting, especially after reading that of Kingsley Just* (letters to the editor). Herewith, a slightly different view in support of Garry, sparked off by Kingsley's letter.

There can be little doubt that some thermals have a significant degree of horizontal rotation — a willy-willy, or dust devil, being the obvious example. Such a thermal may be described as a free vortex, the characteristic of which is:

The product of the tangential velocity v and the radius r is constant; ie, within limits, the tangential velocity increases as the radius of action decreases.

Succinctly: - r * v = constant (ref: Fluid Mechanics R.F. Pao)

If this were taken to a limit, then as radius tends to zero, the tangential velocity tends to infinity! Clearly this does not take place, since other factors come into play, not least being viscosity and inertial forces. These, inter alia, limit the tangential velocity. In the June issue of Soaring Australia (Ref. 1), under Technical Note 4, mention is made of the Rankine vortex, which covers the situation at the core. How closely this model relates to thermals sensed by glider pilots remains to be seen, but it is probably a truism to state that so far as atmospheric activity is concerned, anything that may take place, probably will take place.

Lately, I have taken every opportunity to investigate thermals for rotation and certainly many thermals are more benign when orbiting in one direction rather than the other. So, the more one learns of possibilities, the better is one equipped to gain from them.

The centering of narrow rotating thermals often comes with its own thrills. How often has one soared up into a thermal core, then wished for sufficient rudder authority to spin the glider around its wing tip to float up like a thistle? More often, there is a precipitous descent across the thermal through zones of more slowly rotating air until control is finally re-established. "Dear me", or words to that effect, emanate from the cockpit when it is found that the net gain in height has been zero, or worse.

With respect to Reference 2, Kingsley Just, wrote of the time associated with a Rate 1 Turn. Devices used to determine a rate of turn are calibrated gyroscopic instruments. These instruments take no account of headwind, tailwind, horizontally rotating air mass nor indeed the situation in deep space! Their output is derived solely from the inertia of the spinning gyroscope. An aircraft undertaking a given rate of turn does so with reference to the South Pole, Southern Cross, or any other suitable fixed point in space. Output from a Rate of Turn indicator is a function of angular velocity, which is true airspeed and radius of turn.

For our purposes, the true speed of the aircraft is the sum of the indicated air speed (assuming no positional error in the pitot/ static system) plus the rotational component of the air mass. An aircraft flying in nonrotating air will have, for a nominated rate of turn and airspeed, a fixed radius of turn (bank angle) relative to its air mass. However, in an air mass with horizontal rotation, the same aircraft, flown at the same rate of turn and airspeed, must be flown with an increased or decreased radius of turn depending upon whether the aircraft is flying with, or against, the rotation of the air mass.

NB. This will be further modulated by the inertia of the aircraft. For example, an increased, or higher, true speed will necessitate an increase in bank angle to counter the increase in angular momentum, which is itself a function of the angular velocity.

Our soaring pilot - operating on the fond assumption that the thermal has a bell shaped lift distribution, with negligible skew - will find the advantages of flying against thermal rotation

Rotating Thermals

compound. For a given indicated airspeed, and bank angle, the true tangential velocity, as indicated above, is the sum of the indicated air speed plus the rotational component of the air mass. In this case, the true airspeed will be less than the indicated air speed. This reduction in angular momentum leads to a smaller radius of turn, so enabling the glider to be flown in stronger lift near the thermal core. In addition, the greater tangential velocity of the air near the core, a function of a free vortex (see above) provides greater circulation (lift) over the inner wing, so reducing the extent of aileron input to hold off bank. If the aircraft is flying more efficiently, even greater use is made of the available lift. This latter point may be another useful clue about the nature of a thermal and therefore indicate an optimum direction of turn.

Whilst all the above seems very jolly, the point of the exercise is to offer another view on rotating thermals, but noting, in particular, the reasons Garry gives for flying contra rotation are well stated in his articles.

*Reference:

1. Soaring Australia May, June, July, September 2006, Garry Speight (Parts 1-4)

2. October 2006, Kingsley Just

Rotating Thermals

By Martin Simons

Originally published in Soaring Australia, April 2007

Argument about the possibility of rotating thermals has been going on since at least the 1930s. Letters and articles have appeared at intervals in various gliding magazines ever since. Attempts rave been made to establish whether there is rotation or not by such expedients as throwing out from the glider, quantities of confetti and even toilet roll streamers. None of these trials, so far, has proved anything very convincingly. One reason for inconclusive results is the difficulty of observing the pattern of any such air motions from an aircraft that is, necessarily, itself moving and possibly also circling.

Convergent Flows And Coriolis

When, as we suppose must happen, a quantity of air just above the ground begins to move up to create a thermal, air from the surrounding area moves inwards to take its place (Figure 1).

It is easy to show that wherever there is a convergent flow there will be rotation. The Coriolis effect is caused by the rotation of the earth. When large scale atmospheric motions are involved, the well known result is that winds round low pressure zones rotate anticlockwise in the northern hemisphere and clockwise in the south.

On the smaller scale of thermals (and plugholes in baths), accidental local disturbances are usually more influential than Coriolis. Irregularities of the surface, clumps of bushes, trees, buildings, even passing vehicles, deflect the inward flow from the most direct radial route. There is invariably some slight diversion, imparting some tendency to rotate as soon as the convergence begins. There may be a slight statistical bias favouring clockwise south of the equator, but it is not much more than a weak tendency. Other things being equal (which they never are), the Coriolis effect ensures that there will always be some rotation but this is not apparent in the initial stages. The inward flow only occurs because some air has already started to rise creating the requirement for replacement.

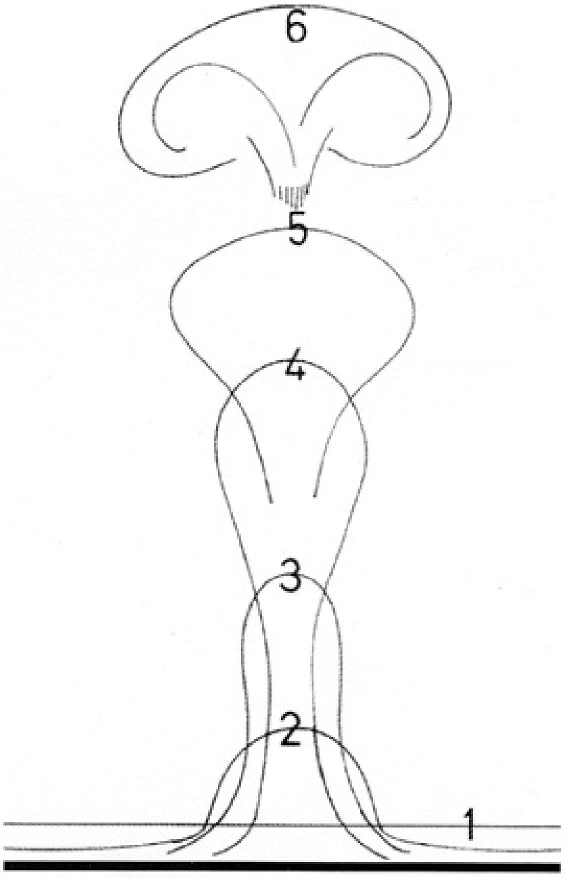


Fig 1. The shape of a rising thermal.
(From Bradbury, Meteorology and Flight, p 47)

1. *A large fairly flat area is heated by the sun and a layer of hot air develops close to the ground.*
2. *A small disturbance or inequality of heating causes a thermal to begin to rise.*
3. *The thermal begins to form a plume, air flows inwards at the base.*
4. *The plume rises further, but the supply of warm air from below begins to diminish.*
5. *The plume is now detached from the source, but continues to rise.*
6. *A vortex ring circulation becomes established as the entire bubble continues to ascend*

Any such rotation, whichever direction it may have, becomes intensified. What began as a relatively gentle inward movement of air, but slightly indirect, is transformed into a rapid spin. This is an example of the law of energy conservation. The effect can be demonstrated with a simple rotatable office chair or stool. School children in elementary physics lessons often do this, not only because it is a useful teaching exercise but because it is fun. (If you didn't do this at school, try it now!) A person sitting on the chair with arms and legs stretched out as far as possible horizontally, is given a slight initial rate of spin. If they then bring their limbs inwards, concentrating their mass closer to the axis of rotation, the spin speeds up. A figure skater uses the same effect. Approaching a chosen point at some speed in a long, gently curved path, with arms and one leg stretched out, then reducing the radius of the turn and finally retracting arms and legs to draw the total body mass closely around the point, the rotation becomes very rapid. The kinetic energy of the approach is concentrated close to the centre and a spin is the result.

The result of a strong thermal taking off from dusty ground, is often, though not always, a small whirlwind or dust devil.

The dust rises in a rotating column. It seems there always are strong and turbulent thermals associated with dust devils. It is not uncommon in arid and semi-arid regions to see several such dust columns starting more or less simultaneously at separate places perhaps a few hundred metres apart. As they writhe upwards the general convergence sometimes brings them all together to form one main column that may persist to a considerable height. Entering a dust devil at a low height is an exciting experience: the air is very turbulent, the angle of bank has to be steep to keep within the lift and the airspeed needs to be rather high to ensure adequate control. If well centred, it is even possible to look down the core of the whirlwind and see the 'eye', which is relatively clear of dust.

As the thermal rises further still, however, it is not so obvious that the rate of rotation persists through the whole upcurrent. It seems probable that a rising thermal acquires a rotating tail but this may not always be powerful enough to raise the dust. In the thermal above the spinning tail the air is relatively smooth. Presumably when this happens the glider has entered the original bundle of air whose initial rise caused the convergence in the first place. This mass of air was probably not spinning when it started to rise. Moreover, as the mass of air rises it expands laterally because the general air pressure reduces. The mass as a whole begins to spread out. Such divergence has the opposite effect to convergence. (Figure 2)

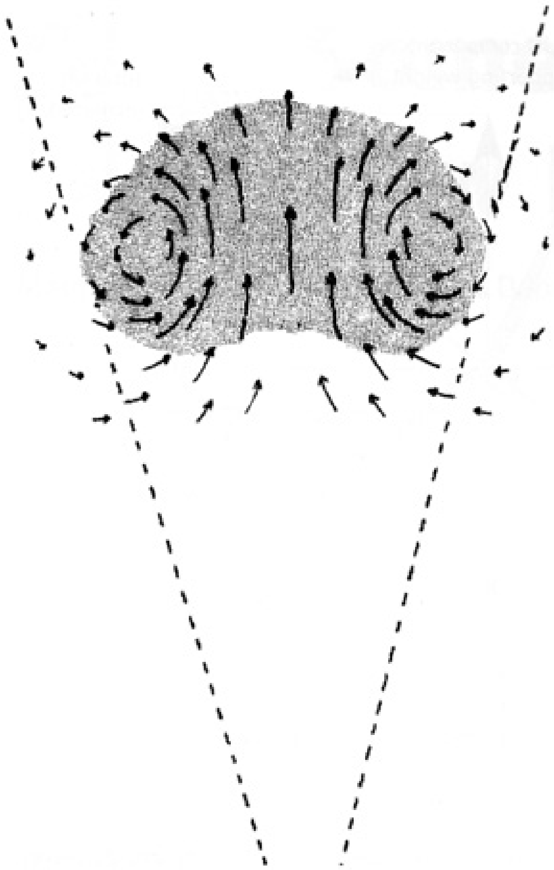


Fig 2. As the thermal rises it expands as a whole. The length of the arrows gives an indication of the speed of the air motion (From Wallington, Meteorology for Glider Pilots, p151)

If there is any rotation round the vertical axis, it tends to fade. (The ice skater can slow the spin down by extending arms and a leg, then skating away on a curved path.) There is also friction and some mixing with the surrounding air, which must slow any rotation down further. So long as air is feeding into the thermal from below the tail continues and spins. It is likely that as the spinning air is drawn into the main thermal, it does carry some of its rotation to the rising core, but dust devils do not persist indefinitely.

The rotating tail itself soon breaks away from the ground. The dust devil is cut off at its base. The main body of the thermal nevertheless continues to rise.

Rotating Thermals

Vortex Rings And Plumes

It is very commonly supposed that thermals are columns rising as more or less vertical currents from the ground up to whatever height is permitted by the environmental temperature lapse rate. Some school textbooks and many of the earliest soaring manuals, show convection currents rising from ‘hot spots’ on the ground with areas of sinking air over cool lakes, forests etc. Such a crude model suggests that any warm spot on the earth will have a sort of thermal chimney permanently rooted on it. This is clearly inadequate. Thermals begin, develop and take off from their source as Figure 1 showed. If there is any wind, or even a slight general drift of the air at ground level, the thermal must in any case drift away from its original source and then continue independently. Commonplace experience in soaring confirms that even well-known thermal sources produce, at best, intermittent bursts of lift separated by periods of quiescence or even sink. Flying over the so-called ‘resident thermal’ near a gliding club, does not always produce lift. Even trying to enter a thermal some distance directly below another sailplane or a whole ‘gaggle’ circling and climbing, does not always succeed. The active part of the thermal, imagined now as a bubble, has risen beyond this point, leaving nothing below but a turbulent wake.

Many other experiences, and some measurements, in soaring support a vortex ring model of the thermal. This was proposed originally by glider pilots but elaborated further by meteorologists such as Richard Scorer in the 1950s and described in the book Meteorology for Glider Pilots by C E (Wally) Wallington (1961, p!51), reproduced here as Figure 2. Developed theories appear in Meteorology and Flight by Tom Bradbury (1989, p49) and in Derek Piggott’s books, Beginning Gliding and Understanding Gliding (all editions, Figure 3 here).

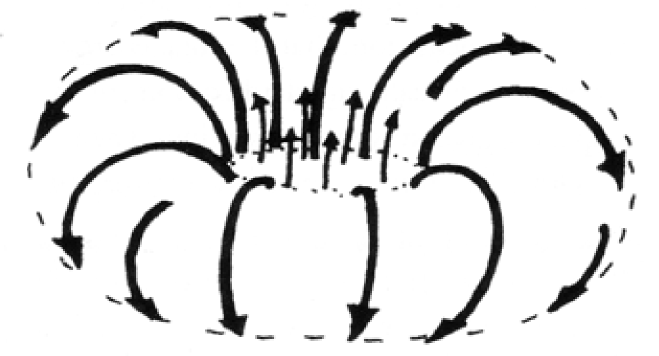


Fig 3. The vortex ring model of a thermal bubble (From Piggott, Understanding Gliding)

If it is supposed that the vortex ring has its own circulation as illustrated, and we also believe the thermal is rotating around its centre in the horizontal plane, this rotation must somehow be incorporated into the vortex ring.

As the diagrams show, as the vortex ring ascends, the air converges on the underside and then is drawn up through the centre. The underside convergence, as described above, will tend to encourage rotation in the thermal core. It is very reasonable to suppose that the influence of the spinning tail will introduce sufficient disturbance to initiate the spin, whether or not this accords with the Coriolis influence. The implication is that when circling in a thermal core, there is very probably, if not certainly, some rotation around the vertical axis. This is not likely to be always in accord with the Coriolis effect. In the upper regions of the rising vortex ring, however, in what is called the cap where the bubble is displacing the surrounding air to rise through it, the air begins to diverge and this must weaken the spin.

Does it make any difference?

The effect on the handling of the glider in a rotating thermal is not easy to deduce but one thing must be appreciated. The forces experienced by the glider and its pilot come from the air, not from any supposed influence from elsewhere. It is a mistake to suppose that the thermalling glider is describing circles within some frame of reference provided by the ground, still less relative to some distant star or to the universe as a whole. There is no fixed frame of reference for the glider other than the air in which it happens to be. Hence forces (which may be described as inertia) acting when circling in a rotating thermal arise only from the motion of the glider and the reactions of the air to this motion. Viewed from the ground, or from the distant stars, certainly the glider appears to accelerate and decelerate, but the path over the ground (which is in any case moving rapidly along round the earth's axis of rotation), or relative to distance galaxies, is irrelevant.

Centrifuge Effects

In a rotating thermal the air in which the glider is flying, is itself following a curved path. (We will suppose in what follows that the pilot keeps the angle of bank and airspeed constant throughout, as far as humanly possible.)

When the glider is flying in the same direction as the thermal rotation, it is effectively in a constant tailwind. This does not affect the airspeed of the glider, which we suppose is trimmed correctly. But, with the centre of the thermal as the reference point, the glider is going round somewhat faster than the airspeed would indicate.

Turning against the thermal spin, there is a constant headwind. In angular terms from the centre, the glider is moving slower.

The standard diagram of forces on a correctly trimmed aircraft turning in still air is shown in Figure 4.

The banked wing directs a proportion of the total lift to the side, producing the turn. The reaction, commonly called centrifugal force, is directly opposed and equal to the lift component. The forces balance, so the rate and radius of the turn is steady.

If the glider is turning with the thermal rotation, there is an additional centrifugal reaction, caused by the thermal spin. The thermal, in a sense, is trying to throw the glider out like a centrifuge. To achieve the required balance of forces requires a slightly steeper angle of bank, to direct more of the lift force inwards. Alternatively, if the bank and airspeed are kept the same, the balance is achieved with a slightly larger radius of turn. The thermal spin, so to speak, does in this case move the glider slightly away from the thermal core.

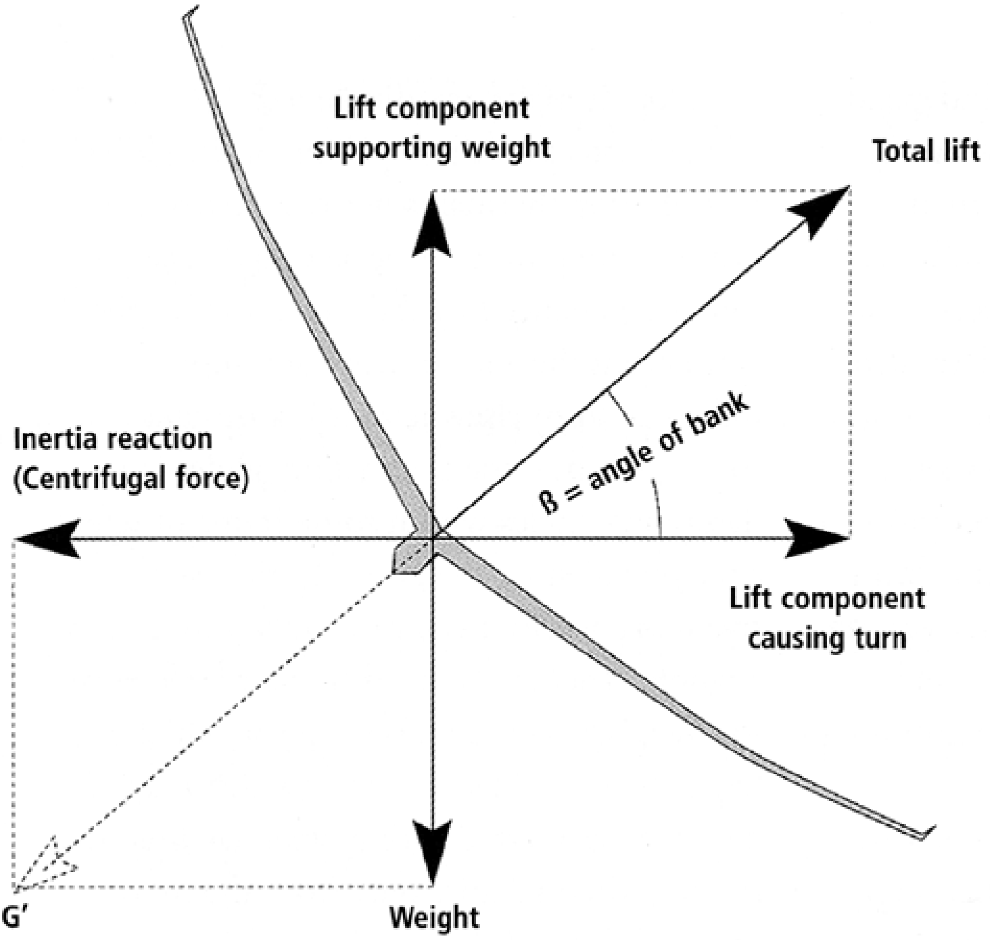


Fig 4. Standard diagram showing turning flight in still air, at constant airspeed and angle of bank

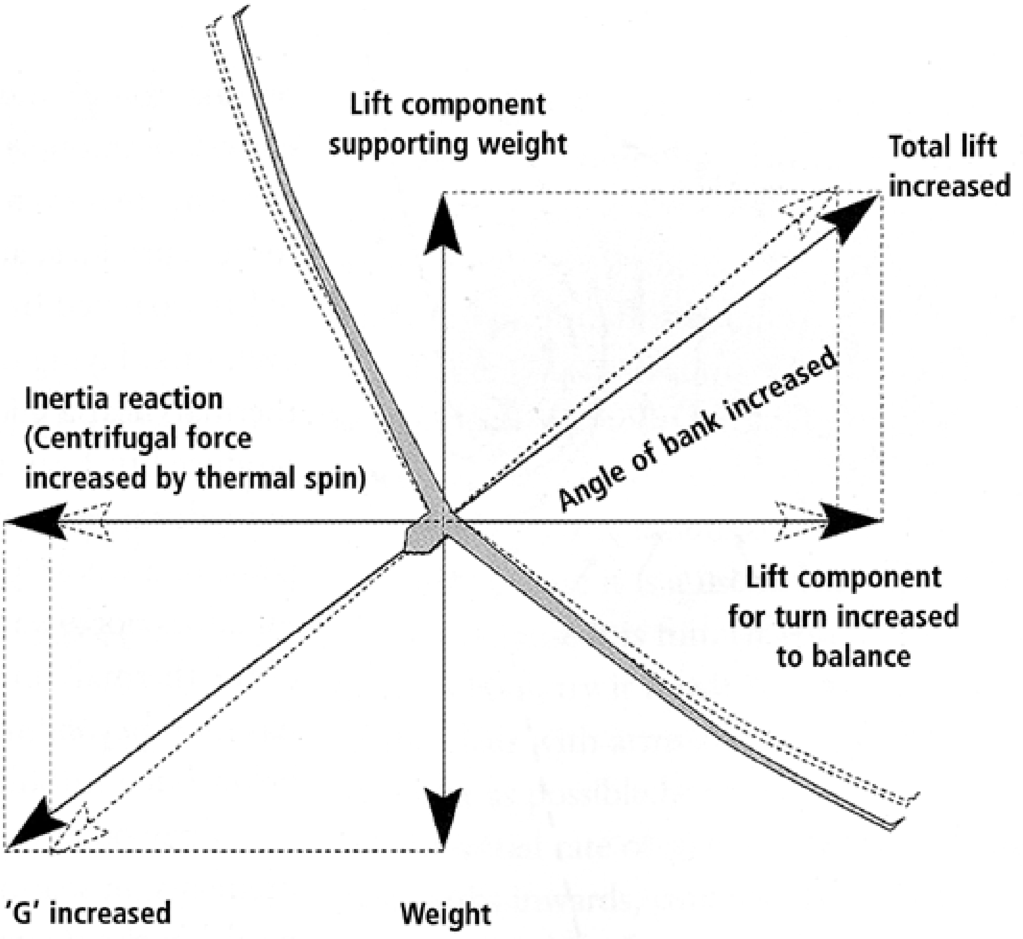


Fig 5. Flying with the thermal spin. Increased angle of bank required. Flying the other way round, reduced angle of bank needed.

Conversely, flying the other way, against the rotation, the balance is achieved with less bank. Or with the same bank, the glider can fly closer in to the core.

And that seems to be all. Unless the thermal spin is very rapid, it seems unlikely that the effect is really going to make a big difference. But if the pilot knows, or believes, that the thermal is rotating one way rather than the other, turning against the rotation will require a little less bank.

The further effects of convergent and divergent flows

There remains another interesting point. An article published in the current issue of Technical Soaring (Vol 29, No 1, January 2007), sets out to show, by measurement and calculation, that the total energy variometer, virtually standard equipment in sailplanes, gives misleading readings when the glider flies into or out of the convergent region below, or the outflowing zone above, the rising vortex ring, or when it circles partly inside and outside the central core. The effect of these more or less horizontal flows is to change the total energy variometer reading in ways that indicate to the pilot that the centre of the thermal is not where it really is.

Possibly, pilots who find that their thermalling is apparently affected by the supposed rotation of the thermal are not quite in the centre even though the variometer assures them otherwise.

Probability In Cross-Country Flying

Commentaries By Garry Speight

Originally published in Australian Gliding, February 1983

Commentary 1

It was just twenty years ago this month that the following article was published in Sailplane and Gliding magazine. The ideas in it were novel at the time and are still little appreciated, even by competition pilots. Yet the logic is quite unanswerable, and the article puts it beyond doubt that the classical MacCready theory, which takes no account of the probability of failing to find the next thermal, gives only half the story about cross-country strategy.

Since no-one has done similar calculations for modern gliders, the numbers are republished just as in the original article. The Slingsby Swallow was a popular single seater of the day with a claimed best glide ratio of 26:1 at 40 knots, while the Skylark 3, a recent World Championship winner, was rated at 36:1, although Derek Piggott suggests that the actual best glide ratios were about 23:1 and 29:1 respectively. For comparable performance in Australian gliders one can think of a Long-wing Kookaburra and a Schneider Ka6.

Incidentally, the thermal strength, height, and spacing chosen in the example seem about right for spring or autumn soaring conditions at some Australian gliding sites.

A Stochastic Cross-Country Or Festina Lente

by Anthony Edwards

Cambridge University Gliding Club

(Reprinted with permission from *Sailplane and Gliding*, February 1963)

"Whatever do you mean by that?"

"By what?"

"A stochastic cross-country? What does 'stochastic' mean?"

"It means that there is an element of chance in the flight: you might not reach your goal."

"But all flights are like that. "

"Yes. "

"Then why bother to call them by a long word when everyone knows this fact?"

"Well, it's like this ..."

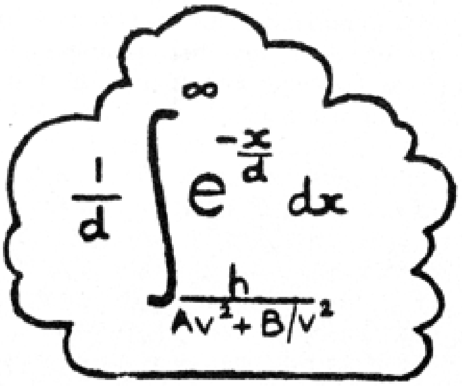
Every cross-country pilot knows that his primary task is to stay up. Only when he is reasonably satisfied about this can he start thinking about the best-speed-to fly, and why Little Rissington hasn't turned up yet, and other such things. And yet, when he comes to work out his best speed, he will certainly not take into account, mathematically, the possibility of a premature landing, although he will do so in his mind ("Better not fly as fast as that . . . might get too low"). But there is no reason why he shouldn't feed the chance, or stochastic element into his calculator. Much is known about Stochastic Processes nowadays, and in this article I want to introduce them to gliding in a very simple example: so simple, in fact, as to be rather unrealistic. But one has to start somewhere.

Today there is no wind. Thin cumulus are randomly dotted over the sky, and I have declared Little Rissington. I am determined not to stray from my track, and a cursory glance at the clouds reveals that thermals will be randomly spaced along the route, every d ft. on average. My operational height-band will be h ft. deep, and — another glance upwards — my rate of climb in thermals will be u f.p.s. And, best of all, no down between thermals! Since Little Rissington is nd ft. away, I'll need about n thermals to get me there. And I mustn't forget my glider — she sinks at $s = Av^3 + B/v$ f.p.s. when flown at v f.p.s. All ready? Right! Hook on, and let's go.

The distance between adjacent thermals is a random variable, x, which is evidently exponentially distributed with probability density $(1/d)\exp(-x/d)$. (Help! He's in cloud already!) If you don't know about these things, just shut your eyes for the next few minutes. Now consider the glide from top of one thermal to the next one, x ft. distant, during which the glider is flown

Probability in Cross-Country Flying

at v f.p.s. The glide takes x/v seconds, and thus consumes sx/v, or $x(Av^2 + B/v^2)$, feet of height. If this loss exceeds h ft., the glider will land; that is, if x exceeds $h/(Av^2 + B/v^2)$. But the probability of this happening is



$$\frac{1}{d}\int_{\frac{h}{Av^2+B/v^2}}^{\infty} e^{-\frac{x}{d}}\,dx$$

which equals $exp[-h/d(Av^2 + B/v^2)]$. Thus the probability of still being airborne after n glides between thermals (which, you may remember, will take me to Little Rissington) is

$P = (1-exp[-h/d(Av^2 + B/v^2)])^n$.

This is the probability of my reaching the goal. A little thought shows that it has a maximum at $v = (B/A)^{0.25}$, which is the speed for best gliding angle, as The Soaring Pilot will tell you. This is as it should be, and we deduce that the maximum probability of arrival is

$(1-exp(-h/(2d\ (AB)^{0.5}))^n$.

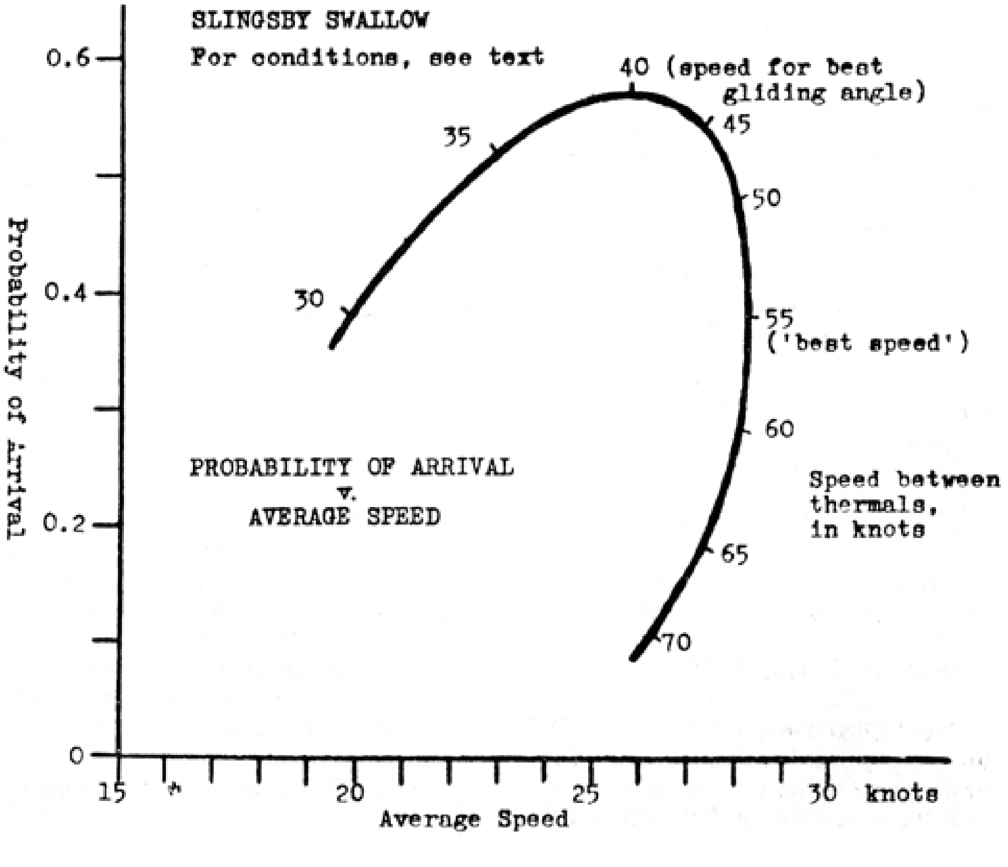
The Soaring Pilot also tells us that the average cross country speed is

$(w = uv/(u + Av^3 + B/v))$.

In order to maximise this I would have to fly faster than my best-gliding-angle speed, as everyone knows, but the probability of my reaching the goal would then be reduced. By how much? Let's look at an actual example.

Suppose Little Rissington is 100 km away, and the thermals are four miles apart on average, d is thus about 21,000 ft and I will need about n =16 thermals. Suppose the operational height-band, h, is 3000 ft, and the rate of climb in thermals, u is 5 f.p.s. If my glider is a Swallow we may guess A=4.5x10^{-6} and B=100 roughly.

Now the last two equations relate the probability of arrival, P, to the average speed, w, by means of the parameter, v. We may therefore draw a graph of P against w, keeping an eye on v at the same time. I have done this in the figure. We



Probability in Cross-Country Flying

see that if I fly at the best gliding-angle speed, 40 knots, the probability of arrival is 0.57, but if I fly at the "best-speed-to-fly", 55 knots, the probability is only 0.38, and the average speed has only gone up two-and-a-half knots. An increase of 10% in the average speed costs a reduction of 33% in the probability of arrival. Is it worth it? Well, that depends upon the object of the flight, whether it is a race or not, and, if it is, what marking system is being used. The expectation of points on any given system can be maximised and the appropriate speed-to-fly found.

A more striking deduction from the graph is what happens around the "best- speed-to-fly". It is often said, quite truly, that so long as one "stuffs the nose down" in between thermals, one will come to within a knot or two of the best possible average speed. Thus, in our example, all speeds between 46 and 65 knots lead to cross-country speeds within one knot of the maximum. But look what happens to the probability of arrival: it ranges from 0.54 to 0.18 — a factor of three!

It is interesting to compare a Swallow's maximum probability of arrival with that of a Skylark 3, for which AB must be about 2.5×10^{-4} compared with a Swallow's 4.5×10^{-4}. It turns out to be 0.84, as against 0.57.

From all of which we may draw two conclusions: if you want to get to Little Rissington, go by Skylark; and, whatever your mount, *festina lente*! We are not all free to choose our glider, but we can all choose our own tactics. Stochastic theory clearly has something to contribute to the theory of tactics, and I hope other pipe- dreamers will continue the investigation. One immediate application is to the task of handicapping, which it could change from an art to a science.

Commentary 2 by Garry Speight

Anthony Edwards' hopes for the application of his ideas have come to very little in the twenty years since he expressed them. There has been no development of stochastic theory in gliding textbooks or articles: even Reichmann devotes only one paragraph to "probability" and gives no useful advice on the subject. No-one has collated any of the data that could be taken from barograph traces concerning the frequency distributions of thermal strengths and inter-thermal distances on a given day.

Handicapping calculations still take no account whatever of the high likelihood of out-landing that the pilot of a low- performance glider faces on every inter- thermal glide. When he lands out, it is assumed that his achieved distance should be proportional to his MacCready speed: this merely covers the case of the task being over-set. Competition scoring usually contains some esoteric calculation relating to the proportion of gliders finishing the course, but this appears to be quite arbitrary. As Anthony Edwards points out, if a pilot knows the basis of the scoring system, as well as the probabilistic features of the tasks, he can vary his tactics so as to maximise the likelihood of a high overall score.

At the very least, surely someone should by now have redrawn the curve of "Probability of Arrival versus Average Speed" for a 300 km task in a Libelle (for example) on a typical Australian summer day, so that pilots attempting Gold Distance could be shown how likely they are to succeed, and how their chances will be affected by their choice of inter- thermal speeds.

Don't statisticians ever take up gliding?

Of course, "The Armchair Pilot" himself, A. W. F. Edwards, is a statistician who took up gliding. In the wider world he is known as "Fisher's Edwards".

Editorial note:

The following expression:
$s=Av^3+B/v$
was given incorrectly in *Australian Gliding* as:
$s=Av^2+B/v$
The following expressions: $(1/d)exp(-x/d)$ and $(1-exp(-h/(2d\,(AB)^{0.5})))^n$
were given incorrectly in *Sailplane and Gliding* as:
$1/d.\ exp.\ (-x/d)$ and $(1-exp\text{-}h/2d\ AB)^n$

When to Circle: When to Leave!

Decision-Making Features For An Air Data System

By Garry Speight

Originally published in Australian Gliding, August 1983

Efficient cross-country flying depends on the use of the MacCready ring or a speed director based on the same principle. The MacCready ring indicates the best speed to fly between thermals for a given value of thermal rate-of-climb.

The choice of this rate-of-climb amounts to adopting a consistent policy about which thermals are to be accepted and which rejected.

In an article called "The Arm-Chair Pilot", published in the October 1964 issue of Sailplane and Gliding, Anthony Edwards invented the term "critical rate- of-climb" for a rate-of-climb to set on the MacCready ring.

Whereas, when using MacCready theory for flight planning or task setting, cross country speed may be estimated by using the forecast average thermal strength, and whereas maximum cross country speed is theoretically achieved by flying according to an accurate estimate of the initial rate of climb in the next thermal, the critical rate-of-climb is neither an average nor a forecast about the next thermal.

Instead, it is a value consciously chosen by the pilot to distinguish lift that is strong enough to be worth using from lift that is too weak to bother with.

Last year, S & G humorist. Platypus, wrote a piece in the August issue called "Kissing MacCready's Ring". In it he also put forward the idea of flying according to a consciously-chosen critical rate-of- climb: "Always set your speed-to-fly ring to the rate-of-climb that you would be happy to accept RIGHT NOW". Platypus called this the MAIROC : minimum acceptable instantaneous rate-of-climb.

To save space, in the rest of this article I will refer to Edwards' "critical rate-of- climb" as CROC.

While the estimation of the strength of the next thermal is little more than a guessing game, decisions on when to circle and when to dolphin through the lift are of crucial importance, and call for the sort of consistent reference point that the MacCready setting can provide.

The enormous success of the early exponents of MacCready theory, such as Heinz Huth and Paul MacCready himself, may well have been due more to their consistent use of only the stronger, yet sufficiently numerous, thermals that exceeded the value set on the MacCready ring, than to the increase in cross-country speed achieved by optimal inter-thermal glide speeds.

MacCready Flying Technique

A speed director, with audio signals for "fly faster" and "fly slower", is especially useful in flying to the CROC concept because, as the glider enters rising air, the instrument advises reducing the speed to the point where, if the thermal exceeds the CROC, the glider will already be back at thermalling speed before the thermal core is reached.

On the other hand, if the thermal is weaker than the CROC the instrument will not advise such a low speed, and the pilot will not be tempted to circle.

Speed directors also advise speed variation in increased and reduced sink. MacCready theory shows that the speed should be varied in this way.

However, a too slavish pilot response, particularly if it includes pull-ups and push-overs with significant "g" loads, is likely to be harmful: drag will be increased, the aircraft may be damaged by fatigue or by gust loads, and the pilot will be kept so busy that his performance and safety may suffer.

The instrument indications should be followed reasonably promptly, though, to avoid persisting with a slow speed in heavy sink, or a high speed in lift, and to take advantage of the way the instrument can bring you to a thermal at thermalling speed.

When thermalling one should continue to circle only so long as the CROC is exceeded. As soon as the lift drops below that value it is time to leave.

If the thermal is considerably stronger than the critical value that you have previously set on the MacCready ring or knob, you should consider whether to shift to a higher critical value.

This will depend on whether you think that the average strength of all the thermals has increased (or is stronger than you thought at first) or whether the thermal is an unusually strong one and not likely to be equalled again.

The correct setting of the MacCready ring will result in long glides that often use up most of the available convective depth, and high climbs in the strongest thermals.

If one knew where the strongest thermals were, one could use the whole depth of the convective layer in this way. Not having this knowledge, one must use a lower ring setting as a defence against bad luck: if you insist on waiting for a really strong thermal to circle in, you may land before you find it.

Dolphin Soaring

Flying straight through thermals that do not come up to your CROC value is the essence of dolphin soaring. If you set the ring too high you will dolphin down to the ground, or at least down to a height where you will be glad to accept zero sink to stay up. If you set it too low you will be stopping to circle in nearly every thermal.

The correct setting, producing the fastest speed, will use most of the available height without dropping you out the bottom. Having said that, if all the pilots in a race were equally efficient MacCready flyers, the one who flew through the most thermals would win. He could go much further before he lost enough height to make it advisable to circle up again.

He would be able to set himself a higher CROC for two reasons. First, the longer stretches of dolphin soaring mean that fewer thermals must be circled in to complete the course: only the very strongest need to be used. Second, among the larger number of thermals that he sampled there would be more strong ones.

Even though the proportion of thermals exceeding 8 knots, say, might be the same for all pilots, the one who sampled the most thermals might find ten of them, enough to get around the course without circling in anything weaker, while a pilot who located only half the number of thermals would find only five 8-knot thermals and would have to circle in weaker ones to get around.

An even higher level of skill (or luck) in thermal finding results in a flight completely within the dolphin soaring regime, without any circling climbs. In this case, if the CROC is set too low there will be a net climb around the course; if it is set too high, a net descent.

The correct setting gives neither net climb nor net descent. In this case the cross-country speed may be read directly off the polar curve against the still-air sink rate equal to the CROC.

Dolphin soaring is a consequence of MacCready flying when the thermal density is high. Efficient dolphin soaring depends on using the CROC to keep a consistent reference for decision making.

Instrument Audio Signals

As I see it, one of the prime functions of a variometer and speed director system is to signal the decisions: — when to circle, and when to cease circling. Both relate directly to the rate-of-climb setting.

When to Circle: When to Leave!
Decision-Making Features For An Air Data System

I find it astonishing that until recently none of the electronic systems on the market has given clear indications for these two decisions.

As the glider runs in to lift, a typical speed director simply signals "Fly slower   Fly slower". If you follow its indications alone you will stall!

For the decision to circle you have either to **read** the ASI or to **read** the variometer and compare it with the setting of the MacCready knob, whose pointer is not at all easy to see.

One system (Peschges) has an optional automatic switch from "Cruise" (speed director audio) to "Climb" (T.E. vario audio) controlled by the airspeed.

This implies that the thermal has exceeded the critical rate of climb (or something near it) but, once the switching has occurred, the thermal strength must again be visually monitored against the MacCready knob setting as in other instruments.

Even if the rate-of-climb actually turns out to be well below critical, this may not be noticed for some time in the effort of centring.

During the climb, each system (except the latest Cambridge) signals absolute rate of climb both on the audio and on the dials. These values are not relevant to the cross-country task, which is to circle only in lift greater than the critical value.

The absolute rate-of-climb must then be repeatedly visually checked against the MacCready knob setting to find out if and when the thermal should be abandoned.

On some speed directors there is one way to get an approximate indication of net lift relative to the critical value; by leaving the instrument in its speed director mode while thermalling.

The airspeed in the thermal has to be kept steady to avoid spurious lift in the dives and sink in the zooms. Nevertheless, I have found this trick so useful that for some years I have been thermalling with my VW3SG in the speed director mode all the time except when below 1000 feet.

Since December 1981 the Cambridge instrument has been advertised with audio indication of net rate-of-climb above the MacCready setting. Interestingly, some clients have asked for a net rate above 75% of the MacCready setting, which is contrary to the common idea that the MacCready setting should be less than the achieved rate-of-climb.

Perhaps these pilots think that a thermal somewhat below MacCready setting should be circled in to see if the core is actually much stronger.

A Decision-Aiding Variometer

As I was convinced that existing instruments, except, in some respects, the latest Cambridge, were not designed to give clear and positive signals for the crucial decision points in cross-country flying, I approached Mike Borgelt to incorporate certain modifications in his Air Data System.

The first requirement, as suggested above, was that the audio of the variometer was to signal net rate-of-climb above the MacCready knob setting instead of the absolute rate-of-climb.

This ensures that any lift weaker than the CROC is not considered to be lift at all, but *sink* that should be avoided, either by re-centring or by abandoning the thermal. At very low altitudes I would set the knob to zero, of course.

Next, to get a positive indication when usable lift is met with on the glide, I asked for the audio vario "lift" signal (but not the "sink" signal) to be super-imposed on the speed director signal. (The two signals are not the same on Borgelt instruments.)

Since the zero of the audio vario is at the CROC, this signal comes in only when the lift exceeds that value, that is, when the thermal is worth circling in.

When to Circle: When to Leave!

Decision-Making Features For An Air Data System

Circling is begun with the speed director still operative so as to be ready for possible immediate return to a straight glide. The instrument is switched to vario mode once the climb has been established. This brings in the vario "sink" signal and the rate-of-climb averager,

At the top of a thermal the time to leave is when the lift falls below the CROC. This is signalled by the change from "lift" to "sink" in the audio vario sound.

To make this signal quite compelling, I asked for a quiet band on the vario immediately below the critical rate-of-climb. This was to help me to notice when the part of the circle with "beeps" became smaller than the part with "wows", by separating the two parts with sectors of silence.

When I had received and fitted the instrument I found that some adjustment of response rate and width of quiet band was necessary to suit my personal abilities and to make the decision points as clear as possible.

The time constant is now about 2.5 seconds, the quiet band of the vario 0 kt to -2 kt, and the quiet band of the speed director ±4 knots (of airspeed) at 50 knots, broadening with airspeed to ±8 knots at 100 knots.

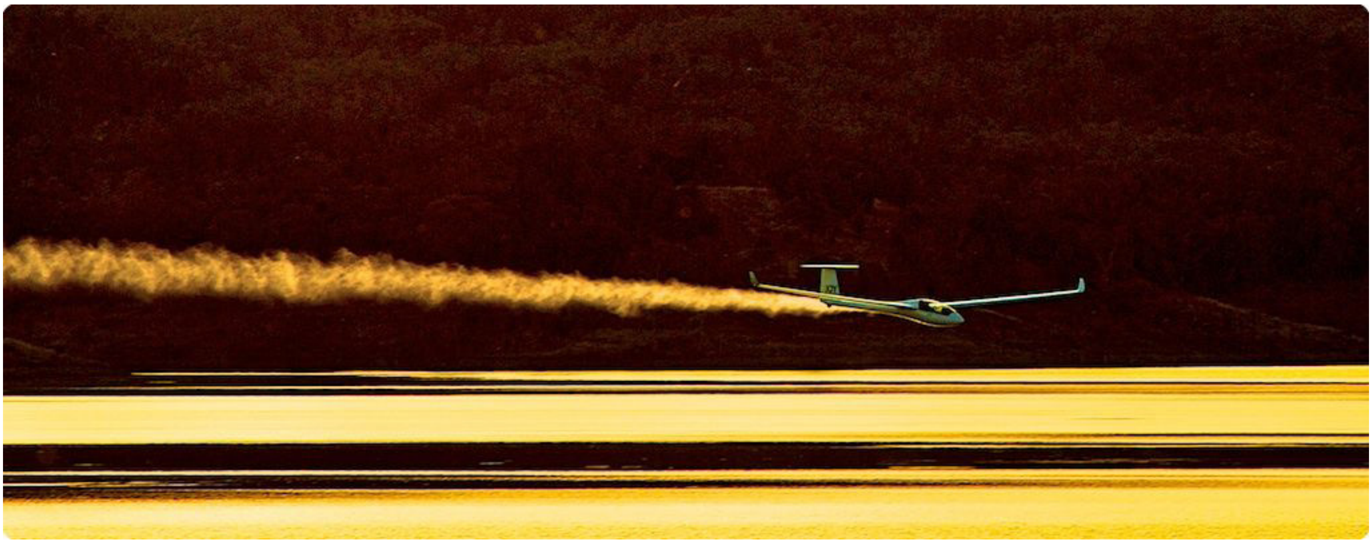
The instrument now works as I intended, giving clear and positive guidance on all routine decisions about circling in thermals.

Changes to the MacCready setting are made from time to time, according to the conditions, such as average thermal strength, altitude, thermal markers, terrain, and changes in the weather. There is no need to be bustled about this; it can be done calmly at leisure.

Decisions about when to circle and when to leave are not made on the spur of the moment, but follow quite automatically from the MacCready setting. The appropriate action is indicated by the audio sound, as follows:

Beeps begin : Circle now!
Beeps continue : Keep circling!
Beeps stop : Go!
No beeps : Don't circle!

After more than a decade, this excellent variometer developed a fault. As happens now to every electronic device, it could not be repaired. I bought a new model, but it lacks the feature "beep above the MacCready value in the climb mode". Cambridge also now lacks this feature. It seems that I am the only glider pilot who sees the value of it. At least most modern variometers display the average rate of climb near to the MacCready value. You can make this vital comparison visually but there is no audio signal of it, as there was in my 1983 instrument.



Climbing Faster

By Garry Speight

Originally published in Australian Gliding, October 1983

If you want to cover ground quickly in a sailplane, you have to climb quickly. You may be an efficient MacCready flyer, and skilled at finding thermals, but you will make slow progress if you can't get the maximum rate-of-climb out of a thermal.

The first essential is accurate flying. The only way to be sure of staying in a thermal is to hold the speed and rate of turn almost perfectly steady.

The speed must be held constant, and as close to the stall as possible consistent with *complete* control of the aircraft in the worst tail-wind gusts.

The bank must be held accurately at an angle that depends on your judgement of the size of the thermal, and the yaw-string must stay in the middle.

Letting the yaw-string wander not only causes enough drag to spoil your rate-of- climb; it. also changes the rate of turn, distorting your circle.

It often happens that a gust blowing outwards from the thermal centre will reduce the rate of turn to zero without affecting the angle of bank.

The horizon is seen to stop rotating past the nose. If rudder is not applied immediately to return the yaw-string to the middle and get the turn going again, the glider will be completely outside the thermal in about five seconds.

Aids to accurate flying in thermals include canopy marks that show both the angle of bank and the level of the horizon in a typical thermal turn, and a well placed yaw-string with a zero-mark.

For a given size of thermal the best angle of bank depends on the wing loading. Heavy ships must bank more steeply.

Some calculations by Ken Caldwell, using my proposed "normal" thermal, give the interesting result that the best rate of turn is practically the same for most gliders: about one circle each 21 seconds.

It is worth practising to try to achieve this rate of turn consistently. I guess that most pilots, like me, take more like 30 seconds if they don't work at it.

Once one's circling technique is adequate, the remaining task is to get centred in the thermal, and to stay centred as it fluctuates and shifts and re-forms.

In a reasonably big thermal the most useful technique is to notice which part ofthe circle has the weakest lift and to shift the circle directly away from there.

In "Cross Country Soaring", Byars and Holbrook wrote in capitals: "NEVER FLY THROUGH THE SAME BAD AIR TWICE". They wrote it four times, including once in *ITALIC CAPITALS*.

The bigger the drop in lift, the bigger the shift should be, but it generally pays to keep making corrections even if the lift is nearly even all round.

Thermals slowly change shape, as you can see by watching the billows in a column of smoke. The point on the circle that has reduced lift on one pass often is much worse the next time around. If you fail to make a correction as soon as you can detect reduced lift, you may find after a couple of turns that the lift has vanished and you don't know where to look for it.

Most mechanical variometers respond fairly slowly to changes in lift so that the part of the circle that actually has the weakest lift may be more than 40° back from the part with the lowest instrument reading.

This does not usually bother a pilot who has practised a lot with a particular instrument, but it can be a problem for one who flies a number of aircraft with different instruments.

Modern electrical variometers are effectively instantaneous in response for the purpose of thermal centring.

The latest variometers usually have an "audio" output as well as a dial. The audio makes a sound that rises in pitch with increasing rate-of-climb, A common convention is to have a chopped tone for lift and an unbroken tone for sink.

The fact that the pilot no longer needs to look down at the instrument not only makes life safer for other pilots in the same thermal, it also makes it easier for the pilot to identify the part of the circle that has the weakest lift, as he can look at the landmarks outside while listening to the variometer.

It is a pity that many two-seaters used for training do not yet have an audio variometer, so that trainees can be taught to keep their heads up.

Stimulation

Until very recently, all variometers indicated, both by dial and audio, the actual rate-of-climb. Centring depended on the pilot's detection of variations in this rate of climb.

Consider a pilot who is working zero sink below 1000 feet. When he knows he may outland in two minutes, it concentrates his mind wonderfully. At the same time the vario is giving a very positive signal about the location of the thermal: "beep" for lift; "wow" for sink. The pilot knows he must get more "beeps" than "wows" if he is going to get away.

By contrast, at 6000 feet in an 8 knot thermal the pilot's "high", brought on by his God-like situation, is encouraged by the instrument, which beeps hysterically in the best lift and only slightly less hysterically in the weakest.

Yet, circling in zero sink should be a rare occurrence related to bad luck or misjudgement, whereas circling in strong lift should make up nearly *half* of a typical cross country flight.

The usual variometer signal thus fails to stimulate the pilot to climb faster except in the one case where he is strongly motivated already!

Some of the more complex variometer systems, incorporating a speed director based on MacCready theory, offer a way of encouraging continual effort in thermals.

Using such an instrument, one can, by leaving it in the ''speed command" mode instead of the "vario" mode while thermalling, get a signal similar to that of a variometer that has its zero displaced upwards to the MacCready setting.

This makes the instrument signal "sink" every time the lift falls below the MacCready setting, thereby spurring the pilot to work harder.

At least two variometer systems now have an option in which the "vario" mode signal itself is displaced upwards to the MacCready setting.

In a previous article (Australian Gliding, August 1983) I described modifications that Mike Borgelt built in to an Air Data System for me, that included this feature. The main purpose was to give a more positive indication of when to circle and when to leave a thermal.

As a spur to faster climbs in thermals, however, this is only a partial solution. Some thermals may be considerably stronger than the MacCready setting, yet one may not wish to fiddle with the setting but to keep it as a consistent reference value. The audio will then scream away in almost as useless a fashion as in a simpler instrument.

Use of averager

Variometer systems often have an "averager" that displays the average rate of climb (or descent) achieved in the last 30 seconds or so.

This was originally intended to give a realistic rate of climb to use in MacCready calculations.

Climbing Faster

It may also be used, however, to stimulate efficient thermalling. It serves as a reminder of what has been recently achieved, as a minimum to aim for in the next circle or two.

One can also, at least theoretically, cross-check between the vario and the averager to see how bad the weakest lift is relative to the average, so as to know how much to shift the circle.

Mike Borgelt has suggested to me that the averager can be made more effective in this role by electronically subtracting its value from that of the vario and using the **difference** to generate the "vario" audio signal.

This provides a pattern of signals like those of the low-altitude zero-sink situation, where "beeps" signal good air to be used and "wows" signal bad air to be avoided, so that the pilot is given the most compelling advice on maximising the rate of climb, the more so if a quiet band is inserted between the "beeps" and the "wows".

It is necessary to ensure that the instrument does not encourage the pilot to persist with **negative** rates of climb, by automatically switching the averager in and out at zero sink.

In fact, it is logical to link the device into the MacCready system by switching it in only when the rate of climb exceeds the MacCready setting instead of zero sink.

In this case the instrument will advise the pilot to begin to circle only when the lift exceeds the MacCready setting, then will give continual advice on the best and worst parts of each circle until the lift falls below the MacCready setting, when the lift indication will cease, signalling that the thermal should be abandoned.

At my request Mike Borgelt has incorporated these modifications into my Air Data System.

I believe that I am now getting clear and reliable advice on how to maximise my rate of climb for the whole time that I am in useful lift, by way of a single audio signal, with no need to look at the instruments at all, except when I decide to adjust the MacCready knob.

Optimal Flight Strategy

By Garry Speight

In this letter to "Sailplane and Gliding" I suggest that Anthony Edwards' ideas about probability and the Critical Rate of Climb should be used in cross country soaring. This led me to propose the practical "Rule for leaving a thermal" in a later article. For that, I also made use of a letter by Jan de Jong, re-published here.

Originally published in Sailplane & Gliding, October/November 1982

Dear Editor,

In Frank Irving's review of MacCready theory developments he summarised an attempt by Litt and Sander to incorporate realistic limits on max and min available altitude, and variable strength and spacing of thermals. The "powers of prophecy" make this analysis quite unhelpful.

The correct strategy for MacCready flying is succinctly stated on the preceding page by Bernard Fitchett: "I set the 'speed-to-fly' computer to the average rate of climb I can reasonably expect if there is an obvious source of lift within reach at this speed, otherwise the setting will depend on one's height. Starting from a great height, you have more chance of finding a strong thermal, consequently I reduce the setting as I lose height or foresee difficult circumstances." Also in June issue (p.111) Platypus was using much the same idea in a computer simulation.

The framework for an explicit model based on this strategy exists in two articles written by Anthony Edwards almost twenty years ago and not yet followed up.

The first point from the arm-chair pilot (S&G, October 1964, p.364) Is that the MacCready ring should be set on the "critical rate of climb". This is neither the average rate of climb used for flight planning, nor the initial rate of climb in the next thermal; it is the min rate of climb that one intends to accept for thermalling. If the next thermal is weaker than the critical value one dolphins through it: if stronger, one circles in it. The inter-thermal glide speed is determined by this choice of a critical rate of climb, but it will be somewhat slower than the optimum speed that one would fly if one could prophesy the exact strength of the next acceptable thermal. However, the main point of this kind of MacCready setting is to guide decisions on which thermals to accept and which to reject.

Bernard Fitchett dearly implies that the critical rate of climb varies with height and with circumstances, including changes in the weather. The way it should vary can in principle be calculated using the concept of probability. This was well presented by Anthony Edwards in his article, "A Stochastic Cross-country, or Festina Lente", S&G february 1963, p.12. Although, as has been repeated ad nauseam, variations from the optimal inter-thermal glide speed have little effect on the average cross-country speed, provided the thermals are closely spaced and of equal strength, in real life the probability of completing the course, or even making it to the next thermal, falls dramatically as the speed is increased.

High speeds follow from high MacCready ring settings, and the probability of coming unstuck due to the steep glide angle is then enhanced by the way one discards weak or moderate thermals that may be the only ones left within range.

A strategy to keep the average cross-country speed up while limiting the likelihood either of a premature landing or of time- wasting scratching at low altitude is a matter of letting the balance of probabilities govern the critical rate of climb. It requires estimates of the frequency distributions of both thermal strengths and inter-thermal distances, and a model of the variation of thermal strength with altitude. Information on these must by now have accumulated on thousands of barograph traces.

From some very sketchy calculations I have made a set of cards to mount on the instrument panel showing the variation of critical rate of climb versus altitude under various circumstances. I believe the use of the cards, by reducing inadvertent risk-taking, is responsible for my very consistent scores in recent competition flights.

Frank Irving replies:

I would not disagree with Garry Speight's remarks, as applied to real soaring circumstances, but I think he is doing less than justice to Messrs Litt and Sander (and hence, by implication, to Helmut Reichmann) by saying that their analysis is quite unhelpful.

I thought I had made it clear in my article that, in practice, the results of such analyses cannot be applied exactly, because they all require powers of prophecy. You have to make do with what you can observe at any instant, but a certain amount of intelligent observation and anticipation is equivalent to a limited amount of prophecy. Such analyses then provide some useful guidance.

It is a good thing that various minds should investigate optimum trajectories, no matter how idealised. They improve our understanding of soaring, they help in the formulation of

"Near-ideal" practical strategies and they may well help in the design of better instrumentation. Who knows, PlatyProg may indeed hold the key to "near-ideal" behaviour?

How Glider Pilots Get There Faster

By Jan L. de Jong

Originally published in Sailplane & Gliding, October/ November 1982

Dear Editor,

I very much enjoyed the article "how glider pilots get there faster" by Frank Irving in the June issue, p20, and I would really like to compliment the author for his excellent survey. Yet, I should like to add a little comment on the rules for the "Litt and Sander optimal flight strategy" as given in table 2. In fact, I should like to propose to replace the rules 1 to 6 by the following two equivalent rules.

A. In any thermal climb only high enough to reach a stronger thermal at minimum altitude by flying with a MacCready ring setting equal to the present climb rate.

B. If there is no stronger thermal that can be reached following rule A, climb to maximum altitude and proceed with the highest feasible MacCready ring setting with which at or above the minimum altitude a thermal can be reached with a climb rate equal to or larger than that MacCready ring setting.

These two rules are very similar to the rules for the final glide which should read:

A'. In the last thermal climb only high enough to reach the finish at the minimum safety altitude by flying with a MacCready ring setting equal to the climb rate in the last thermal.

B'. If the finish cannot be reached following rule A', climb to maximum altitude and proceed with the highest feasible MacCready ring setting with which the finish at the minimum safety altitude can be reached.

The similarity between the A. and B. and A' and B' is not accidental: it is the result of the important but often overlooked point, that in case of altitude constraints the final glide problem model is more appropriate than the MacCready problem model for a cross-country flight.

Of course, the rules formulated here give the same optimum flight strategy as the rules in Table 2. The reason for reformulating them here is only the hope that in the form presented here the rules may be more easily remembered.

Jan L. de Jong, Eindhoven, Holland.

Frank irving replies:

Dr De Jong's rules are more succinct and elegant than the six they replace: an improvement always to be sought in mathematical matters. I am most indebted to him for bringing them to our attention.

Rules For Leaving Thermals

By Garry Speight

Originally published in Sailplane & Gliding, August/September 1984

In a letter to S&G (October 1982, p230) I criticised a paper about MacCready theory by*1 Litt and Sander that had been summarised by Frank Irving (see "How Glider Pilots Get There Faster", S&G, June 1982, p.120). I said that Litt and Sander's model was so unrealistic as to be quite unhelpful. I have had to revise that opinion, which was expressed in the heat of enthusiasm about applying probability theory to cross-country soaring.

The assumption in the Litt and Sander analysis that bothered me most was that all the thermal strengths and inter-thermal distances were known to the pilot in advance. I now take Frank Irving's point that this assumption is acceptable if its use can lead to insight for real cross-country situations.

A more valid criticism of Litt and Sander's paper is that the analysis was not carried through to worthwhile conclusions.

Rules for Known Thermals

I will discuss the third of their four cases; the case in which the flight is confined between upper and lower altitude limits (as on a flight over a plain and under a sharp inversion) and each thermal has a known strength that is constant at all heights.

Litt and Sander conclude that the MacCready speed to fly between the thermals and the height to climb in each thermal should be chosen according to a set of seven rules. These rules embody a number of alternative procedures depending on the relative strengths of the current thermal and the next thermal and the distance between the thermals. Most pilots would find it difficult to memorise these rules and quite impossible, while flying, to recognise which rule is appropriate to the situation.

In a letter published in the October 1982 issue of S&G next to my own, Jan de Jong pointed out that the rules derived from the model can be reduced to four only. Jan de Jong's reformulated rules not only satisfy his stated aim of making them easier to remember but they are also well-structured, so that it is easy to follow their logic and to single out the controlling factors.

For convenience, I repeat Jan de Jong's reformulated rules here:

A. In any thermal, climb only high enough to reach a stronger thermal at Min altitude by flying with a MacCready ring setting equal to the present climb rate.

B. If there is no stronger thermal that can be reached following Rule A, climb to Max altitude and proceed with the highest feasible MacCready ring setting with which, at or above the Min altitude a thermal can be reached with a climb rate equal to or larger than that MacCready ring setting.

A1. In the last thermal climb only high enough to reach the finish at the Min safety altitude by flying with a MacCready ring setting equal to the climb rate in the last thermal,

B1. If the finish cannot be reached following Rule A1, climb to Max altitude and proceed with the highest feasible MacCready ring setting with which the finish at the Min safety altitude can be reached.

One can see that the rules refer to two kinds of distinction: whether there is a stronger thermal ahead, and whether one is aiming to reach a thermal or to reach the finish line.

On the question of the presence of a stronger thermal ahead, de Jong gives alternative rules that do not at first seem to be closely related to each other.

Following Rule A, if there is a stronger thermal ahead the present rate of climb is the key. It controls both the inter-thermal speed and the height to leave the present thermal. One can see, however, that the inter-thermal distance is also involved, because the glide angle that is determined by the inter-thermal speed relates the height to the inter-thermal distance.

By Rule B, it seems that the present climb rate is irrelevant when there is no stronger thermal ahead. Instead one takes the thermal right to the top. Then one sets the ring on the strength of the next thermal or, if to do that would yield too steep a glide angle, one sets it on a lesser value that will give just enough range.

The two rules actually have a lot in common. The ring setting is equal to or less than the strength of both thermals in each case. Also one acts to ensure that the glide intersects the next thermal at or above the Min altitude.

The two rules can, in fact, be combined in a single rule by making a slight change to the original Litt and Sander model: one that does not materially alter the assumptions but merely specifies what happens at the top of a thermal. I propose that the glider's rate-of- climb at the very top of each thermal should diminish from its otherwise constant value to become the still air sink rate over a small but finite time period.*2

The effect of this change to the model is that, even in the case that there is no thermal ahead that is stronger than the present thermal, if one climbs to the very top there is *always* a stronger thermal ahead. As the thermal strength falls through low values of lift, more and more thermals qualify as "stronger". (In the limit, even the ground of an outlanding field is rising faster than the glider is when the thermal lift has fallen below zero sink!)

By this means the situations specified in Rules A and B are no longer distinguished. The rules may be replaced by a single equivalent rule:

When thermalling, as soon as it becomes possible to reach a stronger thermal by cruising towards it with a ring setting equal to the present rate-of-climb, leave the thermal and cruise at that ring setting.

This rule is a re-wording of Rule A, It is equivalent to Rule B because:

1. One should climb to Max altitude, since only then will the weak thermal ahead be stronger than the current rate-of-climb;
2. The meaning of the phrase "highest feasible ring setting" is specified by two conditions:
    a. Not higher than the strength of the next thermal;
    b. Not so high as to drop short of the next thermal.

These are both covered in the new rule, Condition (a) by the word "stronger" relating the next thermal to the current rate of climb (which specifies the ring setting), Condition (b) by the words "possible to reach".

The very good sense that can be brought out by developing the results of Litt and Sander's paper is evident in the rule given above. Cross-country speed depends directly on the strength of the thermals used for climbing. Clearly one should move on as soon as a stronger thermal comes within range at MacCready speed, and not before.

It is clear from the rule that the ring setting depends not only on the thermal strengths, but also on the inter-thermal distance. It is not surprising that this point comes up, for it is a consequence of the altitude constraints that Litt and Sander were studying.

Final glides

It remains to examine the significance of Jan de Jong's Rule A1 and B1, that refer to final glides. He rightly emphasises the formal similarity between these rules and the rules applying to the rest of the flight. The only significant change is that the words "the finish" replace the words "a stronger thermal" or other words referring to the strength of the thermal ahead. Rules A and B and the equivalent rule above specify how to increase one's cross-country speed by moving on to a stronger thermal as soon as it comes within range. One should continue to do this until there is no stronger thermal between the glider and the goal of the flight. It is clearly not possible to increase one's speed by making use of a thermal that is beyond the goal. The object then is simply to maximise the speed to the goal using the current thermal and the following glide. Even if there is a thermal right at the finish line, its strength is irrelevant and does not appear in the rules.

Rules A1 and B1 then also come down to a single rule; the well-known final glide rule. This rule may easily be incorporated in the other rule given above.

Combined rule

It is possible in this way to condense the advice arising from studying Litt and Sander's model into just one rule:

When thermalling, as soon as it becomes possible to reach either a stronger thermal or the finish line by cruising towards it with a ring setting equal to the present rate of climb, leave the thermal and cruise at that ring setting.

In a race on any day when the strength, location and height of every thermal is known, the pilots who follow this rule will dead heat for first place, at a speed which can be stated before the race begins. Each pilot could have calculated, as part of his flight plan, the height at which he should leave each thermal and the ring setting that he should adopt.

How the ring setting varies

The ring settings in Litt and Sander's examples are different for every inter-thermal glide. It is important to know what these settings relate to. First, they increase with thermal strength. The setting is always equal to, or less than, the strength of the weaker of the two thermals — the present thermal and the next to be used. Second, they decrease with increasing thermal spacing: whenever the thermals are too widely spaced to be reached at a ring setting equal to the rate of climb, a lower setting must be used. Third, the ring settings increase with the altitude at which the thermal is left. Both of the other two effects contribute to this. The stronger the thermals, the higher the ring setting. The higher the ring setting the steeper the glide angle and the higher the altitude required to get to the next thermal. Similarly, if a ring setting lower than the strength of either thermal is needed to get from the top of one thermal to the bottom of the next, the higher the top of the thermal is the steeper the glide angle and the higher the ring setting can be.

Thus, the ring setting varies directly with thermal strength and with altitude, and inversely with inter-thermal distance. We can be fairly sure that these relationships hold in real life as well as in Lift and Sander's model.

The variation of ring setting with attitude is particularly important. While one can perhaps get away with assuming that the thermals are all the same strength or the same distance apart, it is clearly ridiculous to assume that one flies at a constant altitude.

Critical rate-of-climb

On a cross-country flight, the pilot does not know where the thermals are, or what their strength is. Instead of setting the MacCready ring according to a known thermal strength and distance he must select the Max thermal strength that he considers he is very likely to meet before running out of height. Whereas in conditions of known thermals the use of the MacCready ring simply serves to maximise the speed, in real life it has another function of far greater importance: it distinguishes useful thermals from useless ones. As soon as one meets a thermal exceeding the MacCready setting, and not before, one should break off the cruise and circle. This is Anthony Edwards' Critical Rate-of-Climb principle, stated in S&G, October 1964, p364, as: set the ring to the rate-of-climb above which one would elect to circle. He has recently ("Proof of the Threshold Theorem", August issue, p.159) given a geometric proof that, once a ring setting has been selected, the cross-country speed will be increased by circling in lift that is greater than the ring setting and decreased by circling in lift that is less than the ring setting.

For real conditions the clause 'cruise at that ring setting" (until you get to the next thermal) should be replaced by "fly to that ring setting". This means not only cruise at the optimum speed, but also to circle if, and only if, one meets a thermal greater than the ring setting.

A practical rule

We now have the material for a realistic rule for leaving a thermal (and, incidentally, for commencing to climb in the next one):

When thermalling, as soon as it becomes almost certain that one can reach a stronger thermal or the finish line by cruising towards it with a ring setting equal to the present rate of climb, leave the thermal and fly to that ring setting.

Acceptable risk

In this rule the phrase 'almost certain" is not precisely specified, and should be varied in the light of experience. At least in Australian summer weather, I am inclined to suggest "odds 200 to 1 on" that one can reach a stronger thermal. One must be rather careful not to over-estimate the chance of finding a thermal within range for it it is not there one will be out of the race — aux vaches. "Two hundred to one on" sounds very safe, but it must be realised that this chance applies to every glide, and there may be more than twenty glides between acceptable thermals in one flight. This brings the likelihood of outlanding up to one in ten. It is up to the pilot to decide whether such a risk is acceptable or not. Any pilot who considers that the odds of Russian roulette (5:1) are good enough for each of twenty inter-thermal glides has only *one chance in forty* of getting home.

Implications

This rule for leaving a thermal is, I believe, correct. It gives valuable advice about this particular decision. It also expresses the things that a cross-country pilot needs to think about, in using energy from the sky to drive his sailplane:

- the need to find a better thermal
- the probability of finding such a thermal
- the dependence of thermal search range on MacCready ring setting
- the way the ring setting determines the acceptability of thermals
- the equivalence of the rule for thermal search and the rule for final glide.

*1 "Litt, F. X., and Sander, G., "Optimal Flight Strategy in a Given Space-Distribution of Lifts with Maximum and Minimum Altitude Constraints", OSTIV Publ. XV, (Chateauroux 1978)."

*2 For sink to occur, them must be a violation of Litt and Sander's stated assumption that the thermal characteristics do not change with time. However, I wish to eliminate the option of loitering on top of a thermal in zero sink, so I am postulating that if you try to do that the thermal will go away, and you will sink.

Let’s be Iconoclastic!

By Garry Speight

About 2011, I began again to give talks on MacCready theory. By this time it was nearly thirty years since I had published about it. Hardly anyone knew what I had written, and few had thought about the subject.

I gave a talk based on the material in the next article, “Best Use of Thermals”, to those attending “JoeyGlide” at Lake Keepit in December 2012. The response of the talented young pilots was negative: I had allowed plenty of time for questions or comments, but none came.

While my presentation was not perfect, I think the issue was that I was attacking beliefs that are deeply held, never questioned, but wrong. I was breaking icons, and iconoclasts are unwelcome.

When I spoke on the same topic at a Lake Keepit Regatta in February 2014, I was determined to face this problem. I introduced my talk with “Let’s be Iconoclastic!”. To make the point, I tore up copies of a selection of modern-day icons.

(And the response of the middling talented older pilots was very positive! Ed.)

Originally published in Keep Soaring, March 2014

My talk today will be iconoclastic: I intend to smash icons. Here is an icon of the Eastern Christian Church.

[Held up this image]

Because Christians would be upset, I will not tear up that icon.

Here is a modern icon that you will recognise.

[Held up this image]

This one stands for this false belief:

- Deciding when to take a thermal is something that winners do naturally. It cannot be taught.

[Tore up and crumpled the image, and threw it on the floor.]

The truth: Everyone can learn it.

[Held up this image]

This one stands for this false belief:

- No-one has ever studied when to take a thermal and when to leave it.

[Tore up and crumpled the image, and threw it on the floor.]

The truth: Some very bright people have studied it for generations.

Let’s Be Iconoclastic!

[Held up this image]

This one stands for this false belief:

- The MacCready ring just advises the most efficient speed to fly.

[Tore up and crumpled the image, and threw it on the floor.]

The truth: The ring reminds you of the weakest lift you will accept.

[Held up this image]

This one stands for this false belief:

- Set the ring to the strength of the next thermal.

[Tore up and crumpled the image, and threw it on the floor.]

The truth: Nonsense! Do you have a crystal ball?

[Held up this image]

This one stands for this false belief:

- Set the ring much lower than the lift you intend to use.

[Tore up and crumpled the image, and threw it on the floor.]

The truth: Set the ring to the weakest lift that you DO intend to use.

For good measure, here is another icon to smash:

[Held up this image]

Well, perhaps not that icon.

[Held up this image]

This one stands for the false belief:

- Water ballast lets you cruise faster.

[Tore up and crumpled the image, and threw it on the floor.]

The truth: Water ballast keeps you from getting low.

[Kicked the torn crumpled sheets of paper away.]

Best Use of Thermals

By Garry Speight

This is a new article. It gathers together lecture material published in the on-line newsletter "Keep Soaring": "Finding and centring strong lift" (April 2010), "Accepting and rejecting lift" (July 2010), and "Fly fast and stay high with the threshold theorem" (March 2014)

Most cross-country soaring in Australia is done by gliding along tracks that are almost straight, and pausing to gain height by circling in thermals. The speed over the course depends mainly on the rate of climb in the thermals. Flying through lift or reduced sink while on track adds to the speed. However, it is rare to complete a course without stopping to circle. Even that case shows that the pilot has judged that there were no thermals strong enough to repay the time to be spent in circling. Deciding when to stop and circle, and when to move on, are key actions in high speed soaring. Some top pilots rely on intuition: the rest of us can do better by using what is known about these decisions.

In The Beginning: "MacCready Theory"

Following Paul MacCready's World Championship win in 1956, pilots who fitted MacCready Rings to the circular dials of their mechanical variometers also won championships. The MacCready Ring advises the best speed to fly to maximise the cross-country speed. It uses performance data, the rate of climb in thermals, the current airspeed, and the current sink-rate. Most people assumed (and still do) that pilots using the Ring did better because their glide speeds were better chosen. This is unlikely: the glide speed has little effect on the cross-country speed. That is shown by a graph in Anthony Edwards' (1963) paper "A stochastic cross-country..." (re-published here in the article "Probability in Cross-country Flying"). The key to their success is not the airspeed values on the Ring, but the arrow that points to the thermal rate of climb. Once the arrow has been set against a number, the pilot's strategy is: "I will circle only if I find lift stronger than the number I have set." Unlike others, a pilot using a MacCready Ring never wastes time circling in weak lift, unless really low.

Critical Rate of Climb (CROC)

The pilot must judge what rate of climb should be set on the MacCready Ring. To set the Ring near the average rate of climb for the day invites an outlanding. There are two reasons for this:

(1.) These stronger thermals may be too far apart;
(2.) The high speeds advised by the ring give a steep glide angle that makes the glide range shorter.

Anthony Edwards' (1963) "Stochastic" graph shows how risky gliding at high speed can be.

It is prudent to set the MacCready Ring rather low. Again, Anthony Edwards (1964) has good advice, which he calls "The Threshold Theorem":

"(In MacCready theory) the "average rate of climb" is to be replaced by the chosen "critical rate of climb"'. The critical rate of climb (CROC) is simply the threshold rate at which the pilot decides to circle in a thermal."

Here Anthony is making it clear that the MacCready Ring should be set in a way that takes account of altitude and thermal spacing as well as thermal strength. Later (Edwards, 1983), Anthony showed that once a MacCready setting has been chosen (for whatever reason) the pilot should not circle in a thermal weaker than the ring setting, and should not fail to circle in a thermal stronger than the ring setting. He proved that either action makes the cross-country speed slower.

When To Leave A Thermal

I devised a rule for when to leave a thermal (Speight, 1984). It is just like the Final Glide rule, so the two can be expressed together:

When thermalling, as soon as it becomes almost certain that one can reach either a stronger thermal or the finish line by cruising towards it with a ring setting equal to the present rate of climb, leave the thermal and fly to that ring setting.

What is new here is the phrase "almost certain". I am insisting that the pilot should think about the odds of success.

Know What Lift You Will Accept!

It is not sensible to have a rule to use only at the moment when one is deciding to leave a thermal. The reasoning that applies to that moment applies to every moment in the flight. The humorist of "Sailplane and Gliding" Mike Bird ("Platypus") showed what should be done: "Always set your speed-to-fly ring to the rate of climb that you would be happy to accept RIGHT NOW." He called this the Minimum Acceptable Instantaneous Rate Of Climb (MAIROC). The MacCready Ring should be re-set at leisure, as circumstances change. It should not be re-set at moments of urgent action.

I express Platypus's idea this way:

At all times you must know what lift is the weakest that you will accept.

(The weakest lift you will accept is Edwards' Critical Rate of Climb (CROC).)

When you know your CROC, set it on the MacCready ring or speed-to-fly instrument.

With CROC set on the MacCready Ring or speed-to-fly instrument, decisions become automatic. The time to leave a thermal is simply the moment when the average rate of climb falls below the CROC and the time to accept a thermal is the moment when the rate of climb rises above the CROC. Your task is to adjust the CROC so that you can be almost certain of finding a thermal as strong as your chosen CROC at all times.

Sensible Odds

One must fly in such a way that there is not much risk of outlanding. In any case one should avoid getting low because it is hard to fly fast when you are low. I suggested in "Rules for Leaving Thermals" that one should think of "almost certain" as being around odds 200 to 1 on, that is, only 0.5% chance of outlanding. If each glide between thermals is flown with 0.5% chance of outlanding, a task using 20 thermals has roughly 10% chance of ending in an outlanding.

To calculate the MacCready setting that will keep the odds of outlanding down to 0.5% calls for a model of how thermals of different strengths are spread around the sky. I did some crude modelling of this sort that resulted in curves relating CROC to height above landing fields. I did not suggest that the strength of any one thermal changed with height, but simply that the chance of finding a strong one was better at a greater height. Models for soaring days with different heights of convection had curves that did not differ much, and I could not find factors other than height that had much effect. Finally, I settled on a very simple formula.

A Simple Formula For CROC

The formula that I use to set the Critical Rate of Climb on a MacCready Ring or a speed-to-fly instrument is:

CROC in knots is height in thousands of feet minus two.

Late in the day, when thermals are more widely spaced, I use "minus three", not "minus two". This formula suits a Twin Astir or a Hornet, and a pilot at State Championship level. It implies that all soaring days are the same for the purpose of CROC. If convection goes only to 4000 feet, one would not expect many thermals stronger than 2 knots. If convection goes to 10,000 feet, but one is flying at 4000 feet, one should accept 2 knots to avoid getting lower. In fact, at a given height, one should be more cautious on high days than on low days.

Automatic Adjustment Of CROC

With the advent of cheap Pocket Personal Computers, a pilot may have the Critical Rate Of Climb adjusted automatically by a computer during flight. The "glide computer" program "XCSoar" has a routine that does that, using theory developed by John Cochrane (1999).

The use of this routine is described in the XCsoar Manual, Section 6.7 “Speed to fly with risk” (NOT Section 6.13 “Auto MacCready”)

The XCSoar “Speed to fly with risk” uses a MacCready value chosen by the pilot for a height near the top of convection. It automatically reduces the MacCready value as height is lost, down to zero at zero height. The pilot also chooses a “speed-to-fly risk factor”. Only the highest risk factor, 1.0, gives a linear reduction with height. (My thousands-minus-two rule is linear, but has a 2000 foot zero-MacCready buffer.) In XCSoar, a risk factor of 0.1 reduces the MacCready value very little until down to 2% of the height of convection (less than circuit height).

Practical Use Of CROC

Many audio speed-to-fly instruments, when in cruise mode, will signal “fly faster” and “fly slower”, and will also signal (by “beep”) lift that is above the MacCready value.

It is common sense to use these audio signals to make cross-country soaring as efficient as it can be. I do not agree with pilots who simply fly a constant speed between thermals. Nor do I agree with those who use the MacCready setting in ways that conflict with well established theory, or fail to set up their instruments to read as they should. The following practical advice assumes that the pilot is making proper use of well set up instruments.

A cross country flight using thermals should have three distinct phases, repeated many times:

(1.) Glide towards a goal;
(2.) Search for useful lift;
(3.) Circle in useful lift.

Phases (1.) and (2.) may merge into each other. Phases (2.) and (3.) must be distinct, and your decision to circle in the lift must be quite positive. The angle of bank when circling in lift in Phase (3.) is more than three times steeper than it is when searching for lift in Phase (2).

Phase (1.) It pays to fly more-or-less directly towards your next navigation point when you have left a thermal. This stops you from messing about. Having decided on the weakest lift that you will accept (CROC), set that number as the MacCready value in your variometer. Remember to reduce the value of the CROC as you get lower.

Fly a speed that will keep the speed-to-fly audio signal quiet, between the signals for “fly faster” and “fly slower”. Always respond promptly to the audio, but never raise or lower the nose more than a slight amount. Deviate somewhat to where there is a better chance of lift.

Phase (2.) Begin an active search for lift when it seems like a good idea.

Search as you get close to a cumulus, and whenever you feel a burble of turbulence, or get persistent audio advice to “fly slower”. Weave from side to side at only five degrees of bank. Plan to explore the likely lift area thoroughly so that, if you find nothing, you can be sure there was nothing to be found. When sink increases, bank the other way. When lift increases, steepen up and be ready to circle. Never fly straight in lift: like a tennis player, don’t be caught “flat-footed”.

I advise keeping the instrument in cruise mode while searching. Do not deviate much from your track, only deviating fifty or sixty degrees when the lift seems the most promising.

Also search for lift when you have planned a circuit for outlanding. In that case, search on every side of the field until you have to commit to a downwind leg. Then complete the FUST check and *stop searching*.

Phase (3.) Commit positively to a tight thermalling circle when the lift is strong enough. That is, when the instrument signals steadily that the lift is above the CROC. Increase the bank to more than forty degrees, and switch the instrument to climb mode. Have a bet with yourself: “I bet I can beat CROC for the whole of this circle!” If you lose that bet, it is likely that a more cautious pilot will catch you up. You need more practice!

Best Use of Thermals

In nearly every thermalling circle there will be a point of weakest lift (or strongest sink). Move away from it! Every time! When learning this, there is a trick taught by Bill Dinsmore of Camden. He said "When the sink is worst, look out to the horizon over the wing that is down. Note some landmark there, and decide to fly towards it." To move the circle does not require flying straight: just smoothly reduce the bank ("Open out!") and increase it again ("Close in!"). Even in a crowded thermal, doing this carefully need not cause conflict. Most pilots want to re-centre in the same direction. Keep a mental record of the direction that you are moving, so you can recognise a shear.

Remember to raise the value of the CROC with every thousand feet. A five-knot thermal that was very welcome when met at 5000 feet becomes barely acceptable at 7000 feet.

If the average lift falls off to a level near the CROC value, do your best to find a stronger core. Leave the thermal the moment the average lift is below the CROC. Then switch the instrument to cruise mode, and track in the direction you have already decided upon, flying at the best speed.

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"Keepit traffic, Golf Foxtrot Papa, on final, 14, Keepit traffic"

Outlanding, Not Out-Crashing

By Garry Speight

Teaching cross-country soaring technique is mainly coaching. That is, improving a pilot's performance. I have acted both as an instructor and as a coach. I wrote this recent article on outlandings when I became concerned that, while aiming to improve a pilot's performance, I was giving little weight to procedures that keep a pilot safe.

Disclaimer: I am talking about gliders that have no engines. Others are better qualified to talk about the other kind.

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Also published in Gliding Australia, March 2015

On a cross-country soaring flight there is always a chance of outlanding. During a competition task, the chance is small, so long as the pilot is flying several thousand feet above the ground. I have suggested that a pilot, by sensible selection of thermals, can keep the chance of outlanding down to about one chance in two hundred (that is 0.5%). Very cautious pilots may keep the chance even lower, while very bold pilots may habitually accept a chance of around 5%.

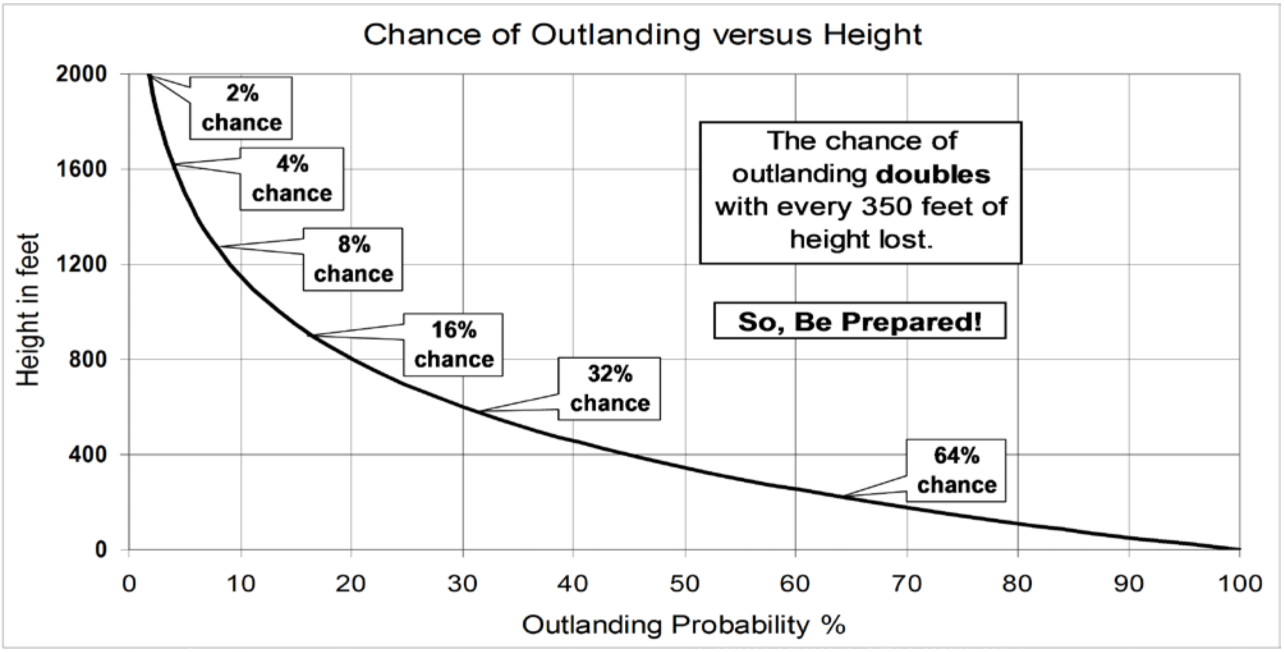
When any pilot flies down through 2000 feet above the ground, the odds are different. The chance of outlanding must increase, because there will be few thermals left within range, or perhaps none!

My first graph shows this increasing likelihood of outlanding. It has nothing to do with how the pilot should cope with the situation, which I come to later. At ground level, an outlanding is guaranteed (100%); at 2000 feet, I have plotted the chance as 2%.

The chance of outlanding increases very rapidly. According to this graph, the chance doubles with each 350 feet of height lost, and that happens every three minutes! Since landing is more hazardous than soaring, it is prudent to give serious attention to landing before the likelihood of outlanding gets much above 10%.

A pilot who has not already thoroughly planned how best to make a safe landing by this stage is in danger. Under the pressure of each new un-noticed hazard, the pilot's errors grow like an avalanche. Often, the result is a crash.

Competent pilots prepare for outlandings in good time; they act in a calm and methodical way that makes crashing very unlikely.



Making Outlandings Safe

Use Standard Procedures

One can imagine landing situations that have very different risks of a crash. At 2000 feet above an aerodrome such as Gunnedah in fine weather, the risk of crashing is very very small, perhaps 1 in 10,000. If that aerodrome became covered in fog, the risk of crashing could be close to 9,999 in 10,000.

Generally, however, a pilot who is soaring cross-country can keep the risk of crashing on outlanding very small (well below 1%) by following standard procedures that are in the GFA training syllabus. Each cross-country pilot will have been "checked out" as competent in these procedures. However, they must be practiced frequently and seriously to ensure that they will help when they are needed. That is really up to the pilot!

Procedures for safe outlandings

The Sequence

The second graph shows the sequence, height, and timing of the procedures that must be followed to ensure the safest possible outlanding:

(1) Select a safe field;
(2) Plan the circuit for landing;
(3) Fly a standard circuit.

Procedure (1): Select a safe field.

During a soaring cross-country flight, you must have a safe place to land at all times. So long as you are above 2000 feet above ground, it is safe enough to simply keep aerodromes, airstrips, and cropping country (not cotton) within range. When you are below 2000 feet above ground things get serious! You must not fail to notice when that happens. You must then identify at least one safe landing place before you get much lower.

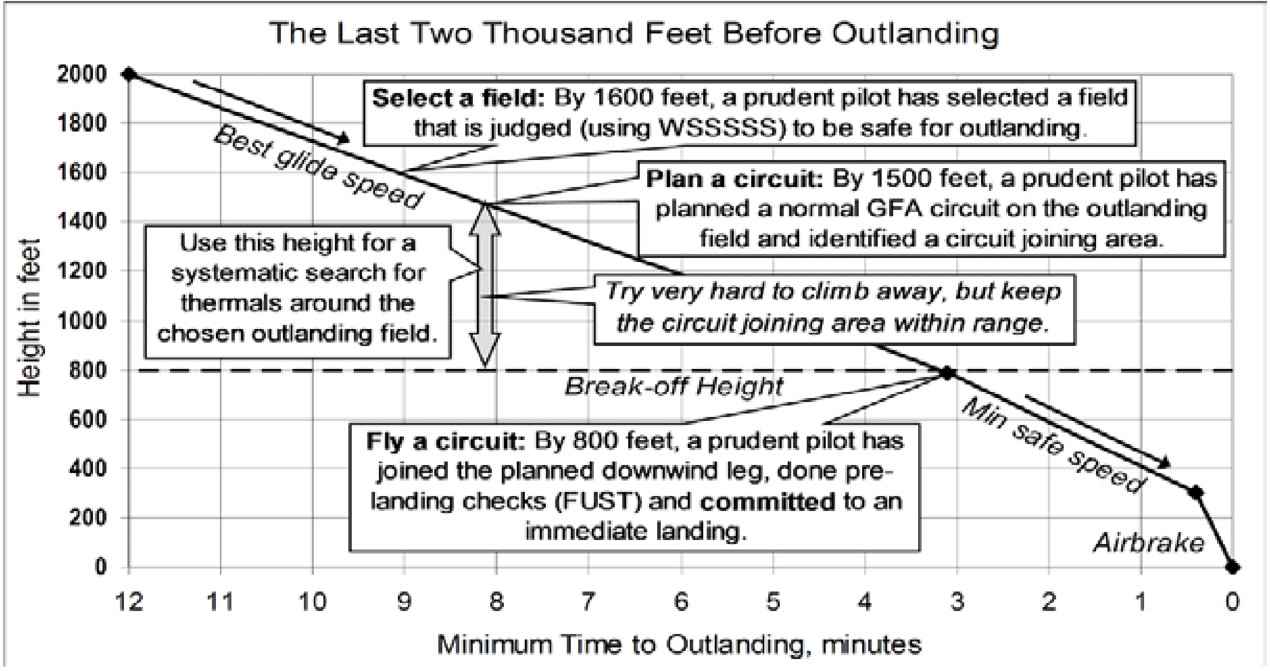
Scan fields that are one or two kilometres from you: near enough to see details, but not hidden under the glider. Given the choice, look at fields ahead on track, so as not to have wasted time if you can continue. A suitable field must meet all the safety requirements (WSSSSS): Wind, Size, Surface, Slope, Stock, and Surroundings. Get this procedure completed by 1500 or 1600 feet above ground if you can.

Procedure (2): Plan the circuit for landing.

As soon as you have decided on a safe landing place, plan the circuit that you will do, just as you would at your home airfield. If circuits to the left or to the right are equally suitable, you can leave that undecided. Identify, and keep in mind, the position of each circuit joining area. You may need them. Get this procedure over by 1500 feet above ground.

Procedure (3): Fly a standard circuit.

Arrive at the chosen circuit joining area at the height that you usually do. (A height of 800 feet above ground is safe: competition pilots in current



practice may be safe a little lower.) Prepare the glider for landing using the standard pre-landing check (FUST). Fly a normal GFA circuit, ignoring any signs of lift. Attempting to thermal away after joining the circuit is very unwise: thermals below circuit-joining height are treacherous.

Catching thermals below 2000 feet above ground.

The three procedures above are essential, and must be given top priority. That does not mean that you can’t thermal. If, by chance, you meet strong, workable lift while doing Procedure (1) or Procedure (2), take it! It will soon lift you back above 2000 feet, and you can move on.

Once you have completed Procedure (1) and Procedure (2) by 1500 feet, thereby shedding a load of worry, you now have 700 feet left to look for a thermal before getting down to circuit height. Sinking at 140 feet per minute, you have five minutes to spare. At 50 knots, you can explore nearly eight kilometres (4.17 nautical miles).

Use your height wisely: plan a systematic search pattern through likely thermal sources. This pattern should end at a chosen circuit joining area.

Your thermal search can have four possible outcomes:

(1) No lift at all: you must enter the circuit for a landing;

(2) One or more very weak thermals, each drifting away: at some point you must give up while still able to enter the circuit;

(3) As in No.(2), but finally there is a good thermal: you climb away;

(4) A first thermal that is good: you climb away.

Mental Discipline

Discipline Is Vital

It takes mental discipline to learn, practice and adhere to these outlanding procedures. But, in any case, mental discipline is essential for success in cross-country soaring. Safe outlanding is just one of many skills to be perfected.

Circuit discipline

Instructors require students to show discipline in planning and flying circuits before letting them go solo. I believe that it is GFA dogma to treat each circuit as a practice for a cross-country outlanding. However, few instructors or students take this as seriously as they should. I find that some students do their pre-landing FUST check well before entering the circuit. When facing an outlanding, putting the wheel down when you still hope to thermal is almost bound to result in the wheel being down when it should be up, and vice versa.

I practice and teach that the pre-landing FUST check marks a decision point. It signals the end of soaring flight, and I will not soar after I have done the check. Because I have this rule, I never do the FUST check any earlier than is necessary for a safe circuit.

Circuit discipline remains vital as a pilot progesses. As a pilot advances to higher performance gliders, s/he should practice doing circuits at heights and angles that are appropriate to a glider of that performance, both at the home field and in outlandings.

Discipline in field selection

The main point is to be alert, and not miss things that indicate that you are less than 2000 feet above a landing place. As the first graph shows, you are at risk if you leave outlanding planning until you are lower.

Getting this low happens quite frequently during cross country flights. That gives priceless opportunities to practice the field selection procedure.

Practice it as a drill!

Usually, there is no-one watching you to see how prudent or careless you are. I realise that I have an advantage there. As I have so often had to demonstrate this procedure to trainees, I have had to keep current in my procedures. That is how it must be for others too.

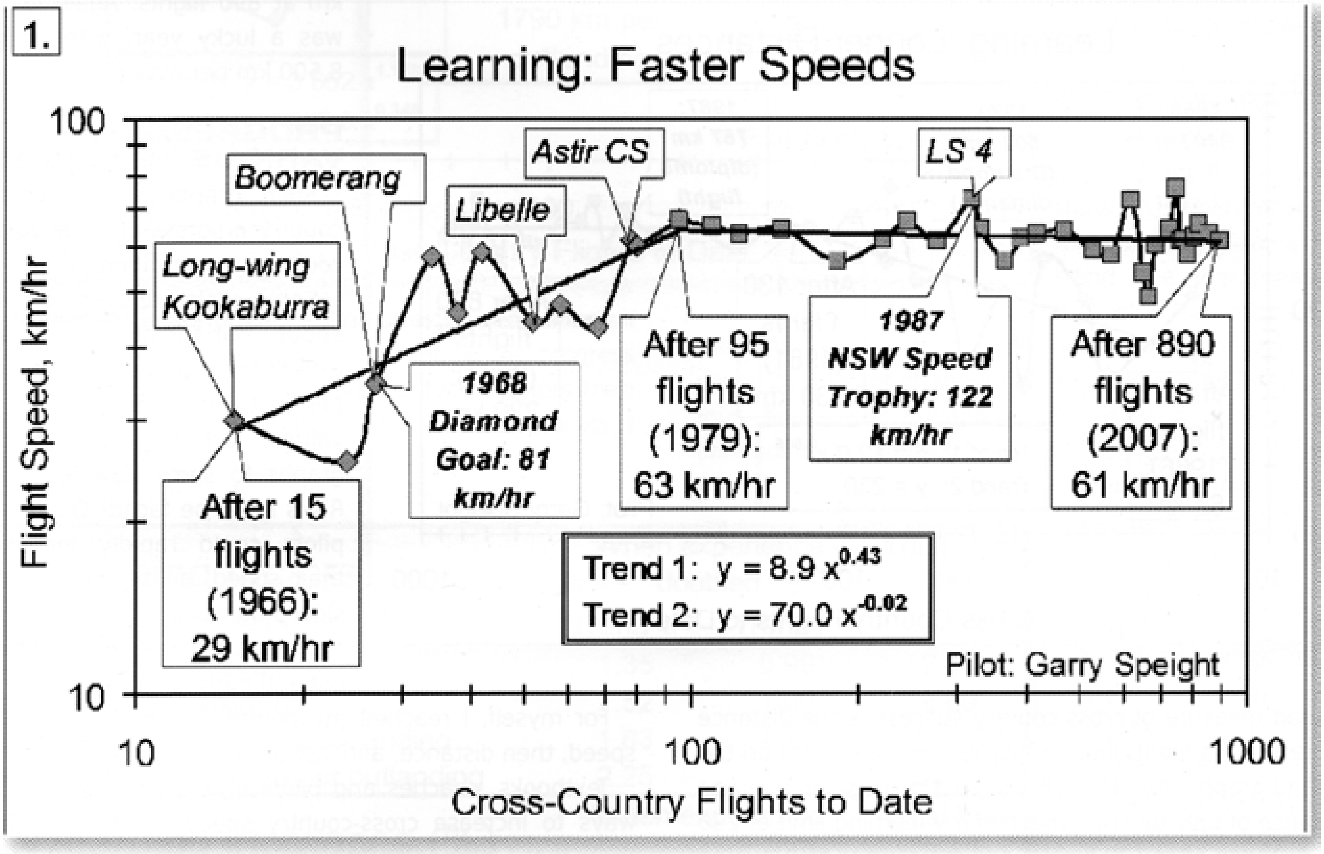
My Brilliant Cross-Country Soaring Career

By Garry Speight

Originally published in Gliding Australia, May 2013

A Long Time Soaring

Begun 48 years ago, my career in cross-country soaring is very long. It has been a success at State level, but I won a National Championship class only once (1997). My logbooks show how I learned to be better at it with more practice. While other pilots must have learned faster, or better, they have not told us about it yet. I hope these graphs and numbers let you see your own soaring flights from another point of view. I am surprised myself at how things worked out.



Where Do The Numbers Come From?

Numbers come from my logbooks: from the summaries that I make on the first of April each year. I make up totals to date, and totals for the year since the last summary. As well as my gliding hours for dual, solo and instructing in various gliders and launch methods, I summarise my cross-country gliding: hours flown, distance flown, number of flights, and number of outlandings. Although my logbooks have details of each cross-country flight, I have not used those details here.

How To Measure Success

I have plotted my progress in cross-country soaring using four ways to measure success: speed, distance, flights per outlanding, and distance per outlanding.

My numbers include all cross-country flights in each year, not just the best. For example, the average distance achieved is the total of all distances divided by the number of flights. My average cross-country speed for a year is the total distance divided by the total flight time. The result is much slower than for a race from a start to a finish. On the other hand, unlike a race scorer, I count speeds to outlandings.

Axes Of The Graphs

Along the bottom of each graph (the x-axis) I do not plot time in years, because in some years I got much less practice than in others. Life events intruded. I needed something that would show my level of experience. I chose the number of cross country flights I had made at the start of each year.

I have used logarithmic scales on the axes of the graphs. This is because learning is not a matter of adding equal amounts of knowledge at each lesson. Knowledge accumulates like compound interest: more and more, exponentially.

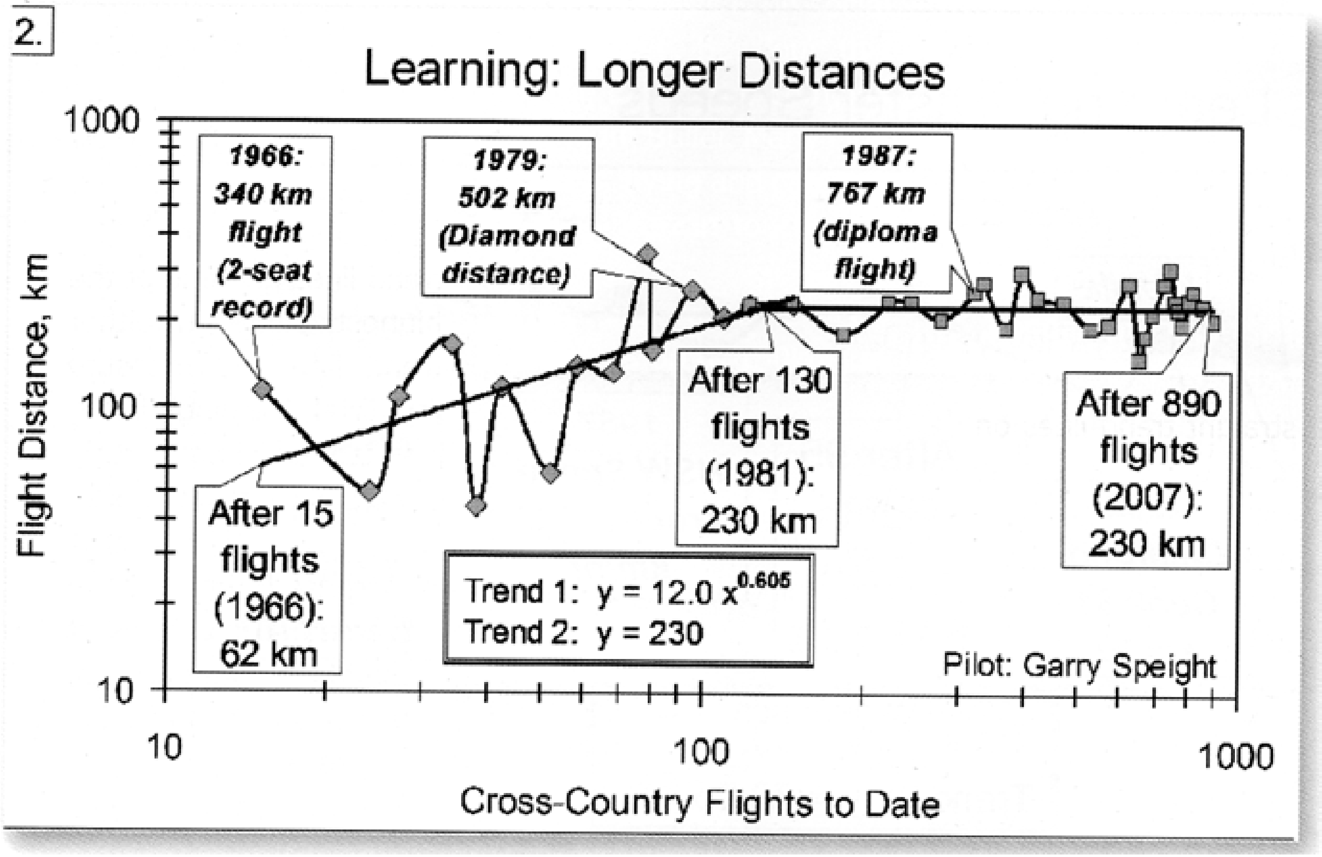
Flying Faster

The first graph shows my progress in learning to fly faster. At first, when I had made 15 cross-country flights, I could only manage an average speed of 29 km/hr. By the time I had made 95 flights, my speed had more than doubled, to 63 km/hr. Increasing the number of flights to 890 did not improve on this speed. In fact, it fell slightly, to 61 km/hr.

The term 'learning curve' is often used carelessly. I think the two straight lines on the graph, taken together, are a learning curve: my learning continued steadily to a point where, quite suddenly, little or nothing more was achieved. Few care to admit that this has happened.

A speed of 63 km/hr seems slow, but I am no slug! From time to time I have flown fast. As noted on the graph, I achieved 81 km/hr on a flight as early as 1968, and I won a speed trophy for 122 km/hr in 1987 and in 1989.

At first, I flew cross-countries in the Canberra Gliding Club's ES52B Long-wing (15 m) Kookaburra, with a glide ratio of 22:1. Club machines I flew later were a Briegleb BG12, ES59 Arrow, E560 Boomerang, and Standard Libelle. Eventually, I flew my own Astir CS and finally LS4a, with good Standard Class performance (38:1). I have marked some changes of glider type on the graph. I can see no effect of glider performance on the speed I achieved. Even if I had been able to fly an LS4a from the start, the curve might have looked much the same.



Flying Further

A second measure of cross-country success is the distance achieved in a flight. Judged by the learning curves on the second graph, after 15 flights I could manage an average distance of only 62 km. I reached my learning limit of 230 km distance after 130 flights, and maintained this level to 890 flights.

Again, my best flights were very much longer. At the beginning (1966), John White and I flew the Kookaburra from near Canberra to Temora and back for a 340-km distance, doubling the 2-seater record. Later, I flew a 502- km Diamond Distance in 1979 and a 767-km Diploma Distance in 1987.

More Flights Per Outlanding

When I had completed 15 cross-country flights, the nine flights in the next year included seven outlandings: only 1.2 flights per outlanding! Outlandings may happen at any time, but learning to avoid them saves a lot of trouble. After 230 flights, the ratio was up to 8.6 flights per outlanding. Improvement then slowed, but I reached 13 flights per outlanding after 890 flights. In 1993 I was lucky to achieve 44 flights for each outlanding.

More Distance Per Outlanding

The average distance I achieved before an outlanding increased from 87km at first, to 1,790 km when I had done 200 flights, and to 2,900 km at 890 flights. Again, 1993 was a lucky year, with nearly 8,500 km per outlanding,

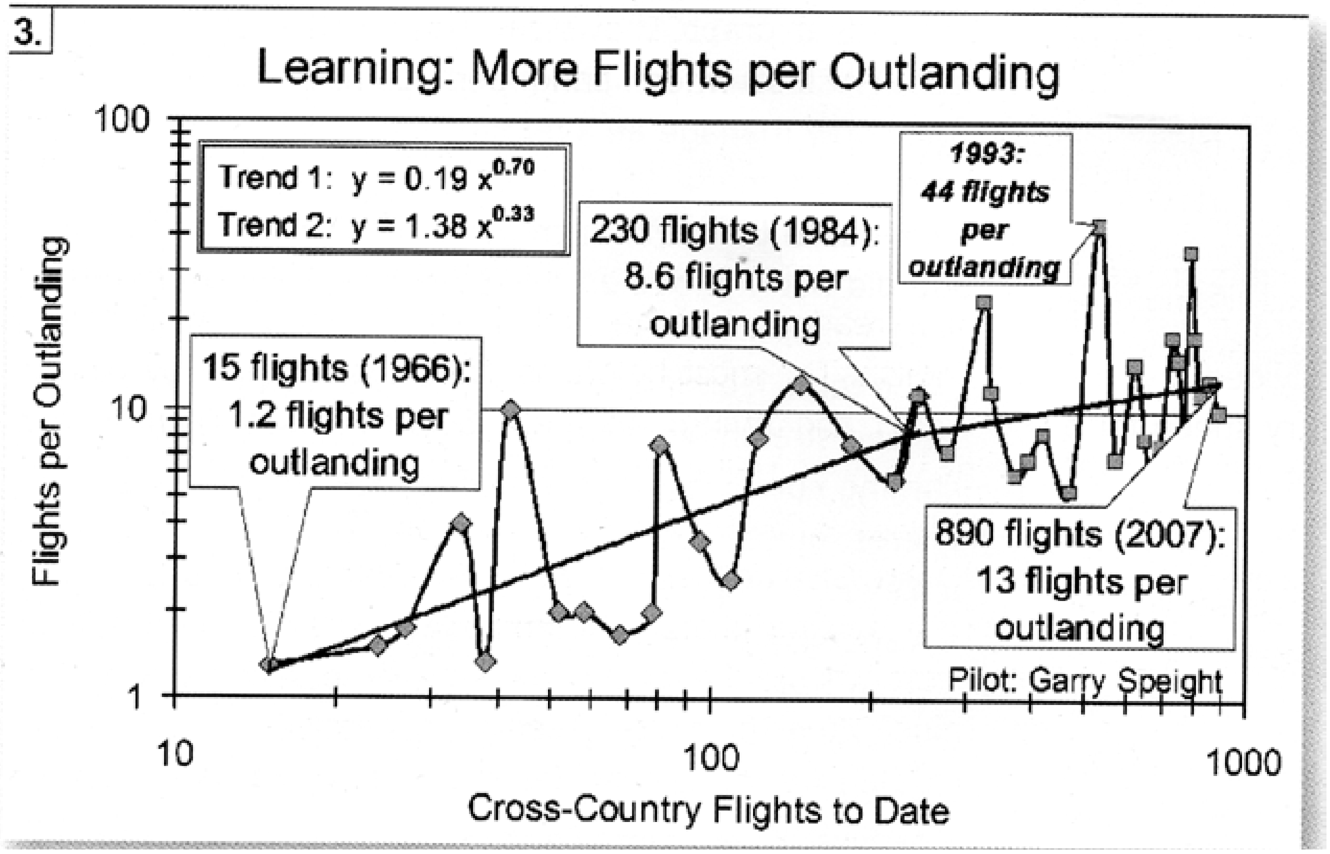
Progress By Various Measures

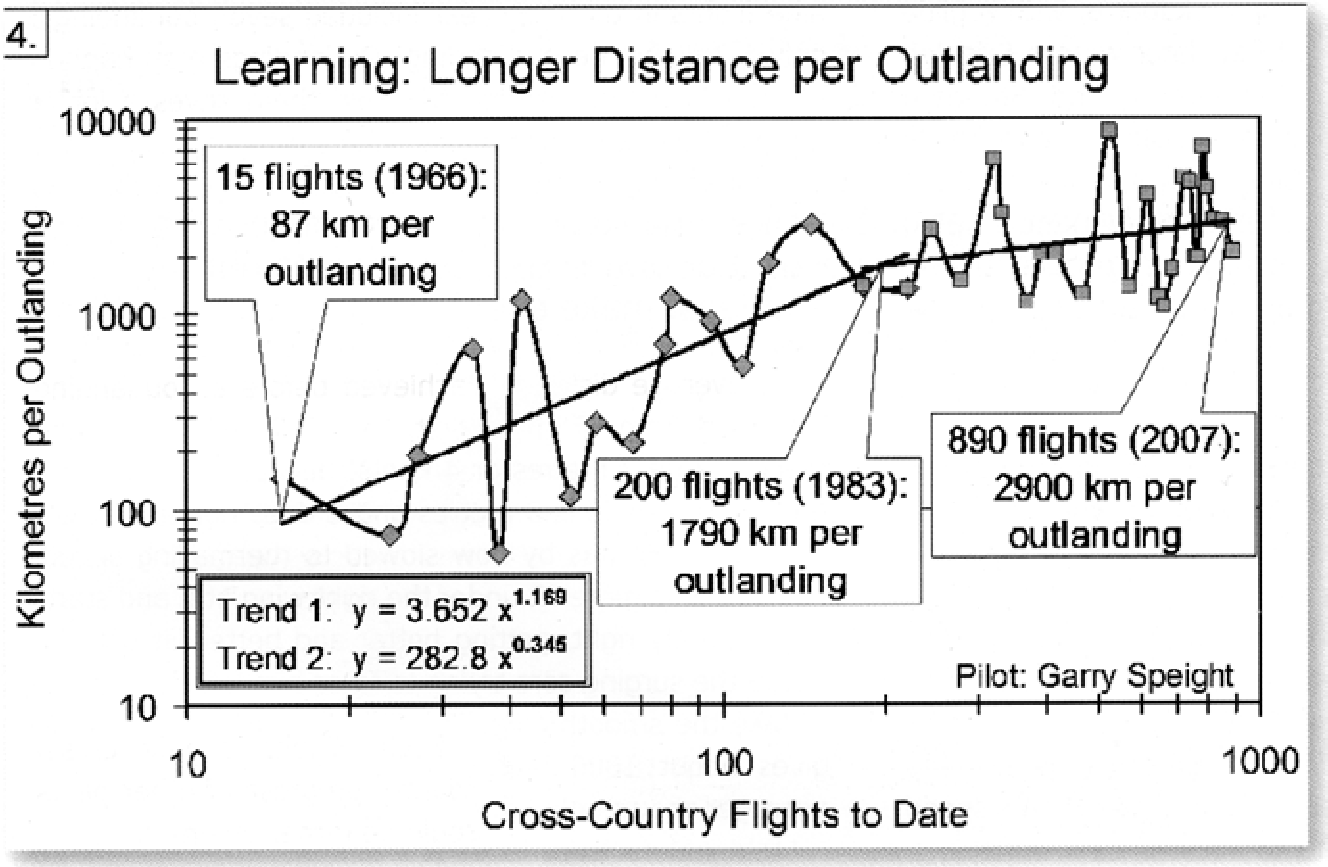
Such graphs of the cross-country progress of other pilots could be rather different. Some pilots are over-cautious about out landings. I would expect the graph of their flights per outlanding to have high values, but the other three graphs to show slow learning. Risks must be faced! Over-bold pilots could rapidly increase their speed, at the expense of slow progress on the other three measures because they so often outland early in a flight.

For myself, I reached my potential in this order: first speed, then distance, and last avoiding outlanding.

Textbooks, coaches and pilots give a lot of weight to ways to increase cross-country speed. Yet, my graphs show that I learned to fly up to my

3.





speed potential quite early: after only 95 flights. To achieve my potential for long flight distance took 35% more flights than for speed. Distance flying needs much more planning, discipline and practice than speed flying. My speed and distance graphs suggest that, after early progress, I learnt little more in the last three decades. The third and fourth graphs are different. First, my time of rapid learning to avoid outlanding continued for much longer, right through to 230 flights. Second, I kept on learning after that, up to the last point of the graphs in 2007. Old dogs do learn new tricks!

Performance And Learning

These graphs show clearly the difference between performance and learning. There is a good textbook on the subject: 'Motor Learning and Performance' by Schmidt and Ginsberg.

My performance is shown by the wavy line through the data points. It goes up and down as I had good or bad luck, problems with gliders and instruments, not paying attention, etc. Learning is when the lessons stick and cannot easily be forgotten. It tends to lead to a steady, permanent improvement in performance. The straight trend lines on the graphs are 'learning curves' that model the progress of my learning. The fact that I did not regress more than slightly in recent years suggests that, within my limits, I had learned well.

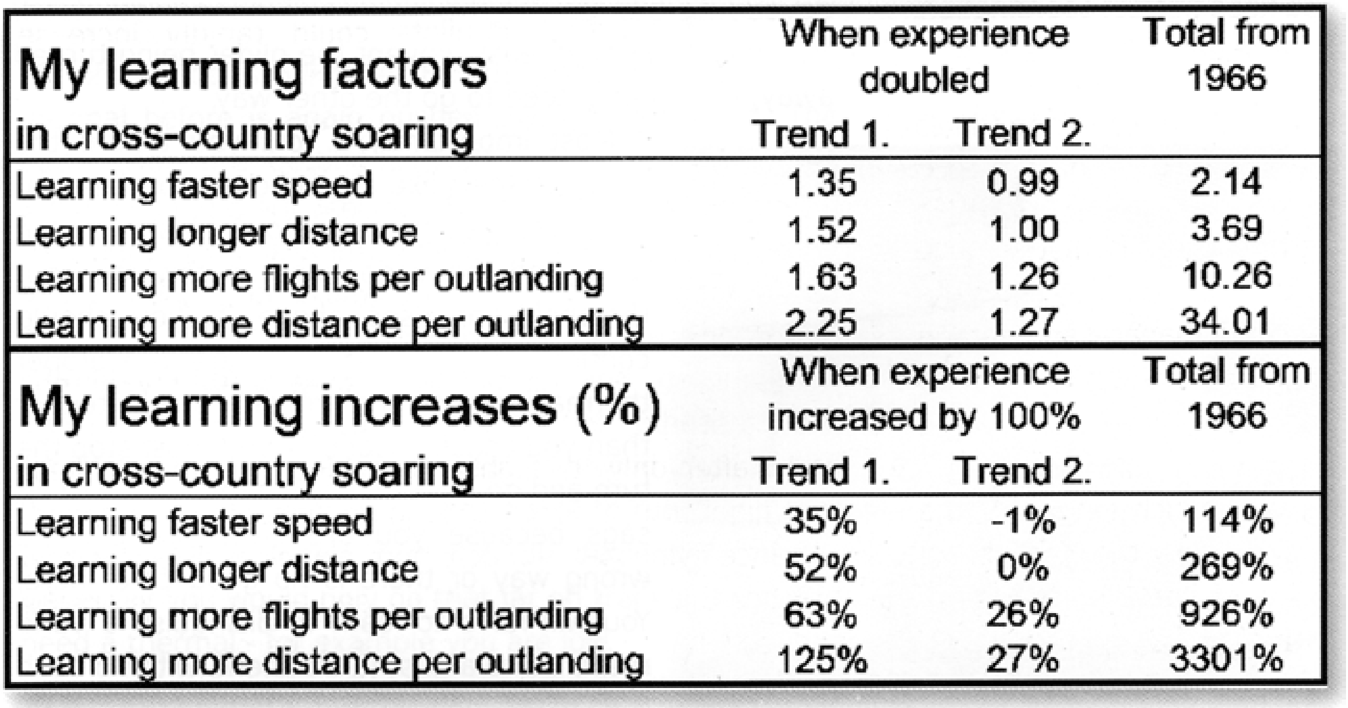
Learning Rates

On each graph, I have given the equations of the trend lines that describe my learning progress. If others do the same, they can compare notes on how well they are learning.

The equations may seem daunting because they are power functions, not arithmetic. One simple way to use them is to mark where the level of experience (x-axis) is doubled and find whether the learning (y-axis) is more or less than doubled. If you prefer percentages, doubling is the same as increasing by 100%.

From the graphs, I have prepared two tables, both showing the same data. The second table "My learning increases %" is easier.

Most of my learning is in Trend 1, early in my career. At that time, for each 100% increase in my experience, my speed went up by 35%, my distance by 52%, my flights per outlanding by 63% and my distance per outlanding by 125%.



My learning factors in cross-country soaring	When experience doubled		Total from 1966
	Trend 1.	Trend 2.	
Learning faster speed	1.35	0.99	2.14
Learning longer distance	1.52	1.00	3.69
Learning more flights per outlanding	1.63	1.26	10.26
Learning more distance per outlanding	2.25	1.27	34.01

My learning increases (%) in cross-country soaring	When experience increased by 100%		Total from 1966
	Trend 1.	Trend 2.	
Learning faster speed	35%	-1%	114%
Learning longer distance	52%	0%	269%
Learning more flights per outlanding	63%	26%	926%
Learning more distance per outlanding	125%	27%	3301%

Eventually, this rate of learning fell from Trend 1 to Trend 2. For speed and distance, my learning ceased, but I held close to the level I had reached. For outlanding avoidance, I continued to learn, but more slowly. Still, my later rate of learning (26% and 27% for 100%) was almost as good as my early rate of learning to fly faster (35% for 100%).

Total Learning

If we start at the beginning of the first trend lines and end at the highest point on either trend line, we measure my total learning. Using the right-side numbers in the first table, I improved my speed by a factor of about two, my distance by a factor of four, flights per outlanding by ten, and distance per outlanding by thirty-four. I am surprised that I have learned so much about avoiding outlandings, which still happen. My improvement in kilometres per outlanding is 16 times greater than my improvement in cross-country speed!

The chosen starting point for the graphs in 1966 is not a true beginning. To clarify, I should say that my first cross-country soaring flight (10 km) was flown with Rupert Brown on 2/2/64. By then I had done 111 dual glider flights, beginning on the first flying day of the new Canberra Gliding Club: 26/12/62. I had come to gliding after 370 hours of RNZAF training in Tiger Moths and Harvards from 1951 to 1956. Perhaps that helped me to learn cross-country soaring, perhaps not.

Coaching

I have seldom been coached in advanced soaring - just one day with Maurie Bradney, and five with Ingo Renner. I have read most of the books about it that are published in English. The most helpful is 'New Soaring Pilot' by Welch, Welch and Irving, Another, 'Soaring Cross Country' by Byars and Holbrook, has the vital advice "NEVER FLY THROUGH THE SAME BAD AIR TWICE".

The GFA now has a National Coaching Panel, tasked with helping pilots to learn advanced skills. I think that pilots should be encouraged to keep records such as mine. Then their rate of learning, relative to each other, and relative to the coaching received, could be judged.

Ready to fly the Twin Astir IKX, 2015

At Garry's 80th Birthday Party, 2014