THERMALING BASICS

By Richard Kellerman

Few soaring skills are more important than the ability to climb in thermals. Here are the fundamentals that every pilot should master.

I can clearly remember when I got hooked on gliding: It was the day I flew a 2-33 for over four hours and was able repeatedly to climb to over 5,000 feet. This struck me as remarkable at the time, and today, about 1,000 gliding hours and four gliders later, it still does. Finding and using lift effectively is basic to all soaring, and although there are many reasons we lose people from our sport, the inability to climb and stay aloft is a major one, and more easily remedied than most.

After a brief consideration of the mechanics of circling flight and the variometer, I have broken the discussion into the basic phases of thermaling: finding, entering, centering and optimizing lift. The important topic of whether or not to stop and circle, and when to leave after a climb has been well covered in a previous article in *Soaring* [1].

Flying skills

Effective use of thermals requires the ability to fly a true circle - constant bank angle and airspeed - without reference to instruments. This is a fundamental skill that must be almost automatic. A strong preference for one circling direction can be a handicap either when entering thermals already occupied by other gliders or by encouraging turns in the wrong direction.

There is no single bank angle that's always suitable, but 45 degrees is a good place to start. Shallower bank angles can keep the glider out of the best lift and slow the centering process; steeper ones quickly increase sink rates. A 45-degree bank is steeper than many pilots imagine it to be, so it is worth noting that a 45-degree banked circle takes about 16 seconds to complete, and places the diagonal screws on the variometer parallel to the horizon.

You must be able to fly safely with other gliders. This requires that you develop the habit of seeing all nearby gliders (and keeping track of what they are doing), and that you know how to enter a thermal that other gliders have found (briefly, you start with a circle that's a bit too large and then tighten it to match the other gliders' circles).

Instruments

An audio variometer with total-energy compensation is important. Without TE compensation, any movement of the elevator produces an unwanted climb or sink indication. Without audio, a potentially dangerous amount of time must be spent looking at the variometer. It is unfortunate that many training gliders lack good varios; this needlessly adds to the difficulties of students learning to climb.

All varios exhibit an instrument lag, generally about 2 seconds. This arises in part from the instrument itself, and in part from the fact that variometers necessarily respond to height changes and it takes time for the glider to change height. I find faster varios to be of limited use, and have modified my expensive fast vario to make it an expensive slower one.

Searching for Lift

Finding lift is like picking stocks: In a bull market everyone does pretty well. In typical markets, good stocks are to be found, but only by those who make use of all of the information available, who are systematic in their approach, who are neither greedy nor impatient consistently succeed.

When Cu Are Present

Cumulus clouds are by far the best indication of lift. But often matters are not as simple as just flying under a cloud and finding a thermal there. Large and inviting clouds may arise from small thermals that can be hard to locate. Patience is essential, and the search for lift under cu needs to be systematic. The time and place to begin to understand the day's lift is right off tow. This should include noting whether lift is on the upwind or downwind side of the clouds, its location with respect to the sun, and its strength at various altitudes. It should be possible to relate lift to the appearance of clouds, to estimate the lifetime of clouds (this can also be done on the ground), to get a good feel for the size of the day's thermals, and to begin to develop a mental picture of the wind.

In the Blue

Beginners and even experienced pilots are often needlessly unhappy about flying without any cu for guidance, but it's not all bad when the conditions are blue. No clouds mean no cloud shadows, so lift can be stronger and more widespread. No clouds mean no cloudbase so the height of the lift is controlled by the inversion, not the condensation level. But with no clouds, it is essential to pay a lot more attention to the many other thermal clues.

My first cross-country flight in the blue was at my first contest. The task: a seemingly unreasonable 140 miles with not a cloud in the sky. I went through the gate in doubt only as to where I would land out. I didn't, and since I flew very slowly indeed, I had no help from other gliders. I simply flew downwind over ground features that I had read might promote thermals – and found them. A more experienced racing pilot now, I am often content to be part of a migrating flock, repeatedly transforming itself from a string of beads to a helix and back again.

The Importance of Going for the High Ground

Thermals favor high ground, and high can mean a few hundred feet. Where I do much of my flying the basic terrain level is 500 ft msl. Hills are seldom more than 1,000 ft msl, but 500 ft makes enough difference to justify a deviation. There are good reasons for this: Air ascending a hillside continues to be heated, the angle of the hillside may allow it to capture more radiation, sloping ground is

ABOUT THERMALS

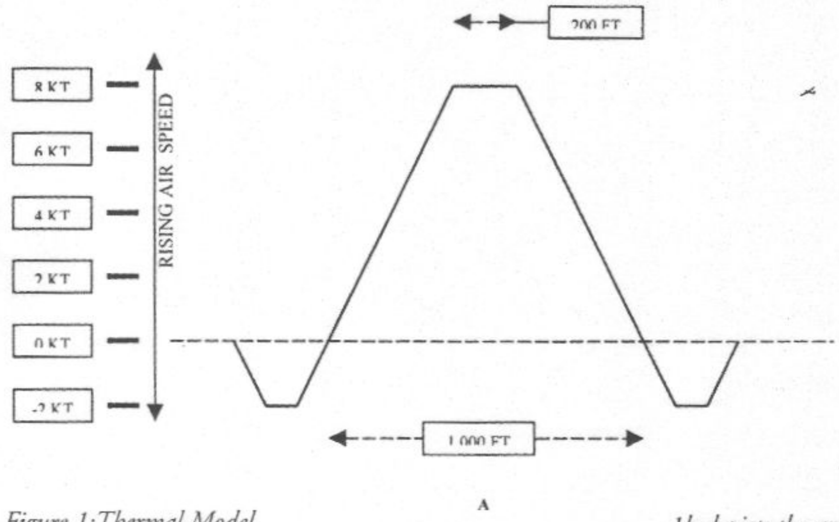
- Thermals necessarily start out as a large, shallow area of heated air, buoyant in the cooler air that surrounds them, but unable to move because of the enormous drag that would be associated with any upward motion. This allows for significant heating of large volumes of air.

- A trigger of some sort is needed for the heated air to ascend. The trigger could be many things, but all effective triggers make it possible for air to begin ascending in a relatively narrow column somewhere within the pancake of warm air. Once this happens, there is no stopping the process. The entire volume of unstable air starts to flow into the trigger area and a thermal is born.

- Our model thermal (Figure 1) is circular and about 1,000 ft in diameter. It's surrounded by a region of sink, and the strength of the lift increases towards the center of the thermal [5]. Experience (most of mine on the East Coast) suggests this is a reasonable assumption. Thermals significantly smaller become hard to use. Larger thermals are nice if you find them, but they still need to be centered.

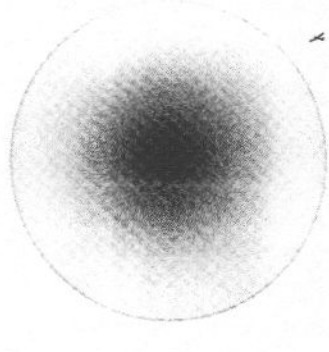
- The diameter of thermals generally increases with increasing altitude and clouds are generally bigger than the thermals feeding them.

- Gliders are small in comparison to thermals; circles often aren't.



A

Figure 1: Thermal Model. 1a depicts the speed of the rising air across the thermal. There is an annular region of sink. The area of lift is 1,000 ft. in diameter, with a core of 200 ft. The lift increases linearly from -2 kt to +8kt. Note the vertical axis is speed, not height.



B

1b depicts the area of lift viewed from above. For clarity, the region of sink is not shown. the 15-meter glider at 2 o'clock is to scale.

- It takes about 10 seconds to traverse the diameter of the model thermal at 60 kt, about 13 seconds at 45 kt.

- For a glider flying at 45 kt, in a 45° bank, the circle diameter is about 360 ft. The table shows how the circle grows with decreasing bank angle, and increasing airspeed.

- Usable thermals are spaced, on average, at least every 10 miles. This can be seen from an examination of GPS flight data and barograms.
- A thermal every ten miles and a glide ratio of 20 suggest that cross country flight in indeed possible, since to fly 10 miles will cost about 1/2 mile (2,640 ft) of altitude.

Airspeed	45 kt	50 kt	55 kt	60 kt
Bank Angle	CIRCLE DIAMETER, FT			
30°	440	540	660	780
45°	360	440	540	640
60°	250	310	370	440

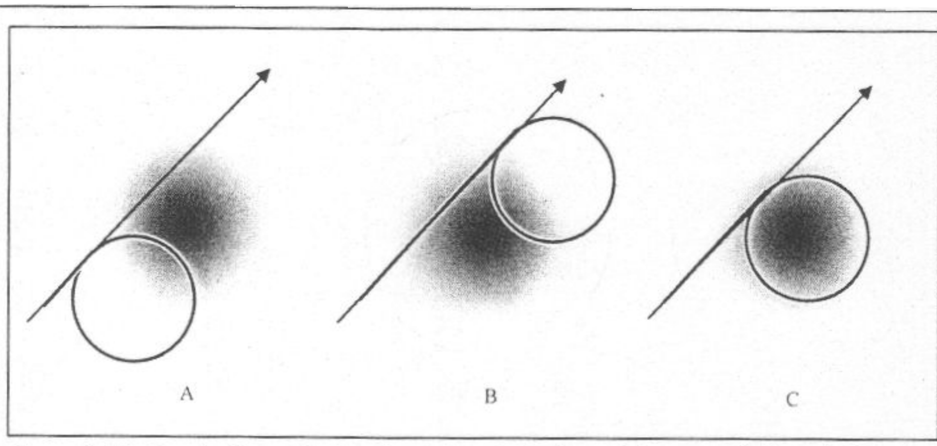


Figure 2: Timing the Turn. Getting the timing right always helps, even if things don't go quite as well as they have for Pilot C. A) Too soon. Even with the correct turn direction, Pilot A gets to fly in sink. B) Too late. Pilot B also flies in sink, but at least he knows where he has come from. C) Just right. Pilot C is almost centered in the first circle. Note that he started his turn as the lift began to decrease.

drier, hills act as triggers, and if there is any surface wind there is an additional impetus for rising air.

My first trip to New Castle, Virginia: "As soon as you're off the high ground, start thinking about landing, because that's what you are going to be doing pretty soon." Advice from the always helpful "Admiral" Hank Nixon.

Triggering

Thermals do not require triggering – unstable systems have fluctuations that sooner or later become triggers themselves. But triggering features such as buildings, local hot spots (fires, factories, rock faces, etc.) will usually beat random fluctuations to the draw. Once the concept of a large surface-bound pancake of unstable air is accepted (see sidebar), the search for thermals reduces to the search for surface features that encourage heating and features that might act as triggers.

Local Convergence

When air moves from a flat (low friction) region to a region with features that slow the airflow, there is horizontal convergence and vertical motion. This can act as a trigger. Some examples: Wooded areas, the edge of a lake, towns (which are also local hot spots and so doubly effective when there is surface wind), and of course any kind of higher ground.

Aerial Clues

I never second-guess birds, either in finding lift, or in centering it. Soaring birds have about the same sink rate as gliders and a much lower wing loading[2]. Even without all the extra practice they get, they are going to be hard to beat.

Other gliders are obvious indicators of lift, but it is worth keeping in mind that misery loves company, so it is essential to assess the climb of a circling glider or a gaggle before rushing off to join in – it's discouraging to leave a weak thermal and join a gaggle that's not climbing at all. And since safety requires constant awareness of all nearby aircraft, it really is inexcusable to stay in weak lift while a nearby glider climbs well.

Entering Thermals

Timing the Turn

Modern gliders are very efficient at extracting energy from the air. In cruise, they fly at a low angle of attack (AOA). When they enter rising air the AOA increases, much as it does when the pilot pulls on the stick. This causes the glider to slow down and accelerate upward. A glider in unaccelerated flight at 50 kt encountering a 5-kt updraft will see an increase in the AOA of about 6 degrees. This is a large change, given that the full range of the AOA is generally only about 20 degrees.

Thus, any thermal worth climbing in will usually impart enough vertical acceleration to the glider both to indicate lift and help in timing the turn. This acceleration is the single best indication that useful lift is present, and that the time to start the turn is fast approaching. It suffers no instrument lag and is proportional to the strength of the lift.

Timing the turn is important – making corrections for mistimed turns takes time, and even more time is needed to make up the altitude lost circling in bad air. Figure 2 makes it clear why correct timing matters.

Anxiety when low, excitement when high, and perhaps an element of wishful thinking, make it easy to start the turn too soon - this is a very common error. There is no sure way of knowing the optimal time to turn, but for the model thermal the rule of thumb of counting to three after getting a good indication of lift is sound. A better approach is to rely on the variometer: with a 2-second lag, at 50 kt, the glider is about 160 feet ahead of the vario, so starting the turn at the first indication of decreasing lift will position the glider nicely.

Entering on a Diameter

Entering a thermal on a diameter (Figure 3a) guarantees that the turn will be the wrong way. It is important to remember this

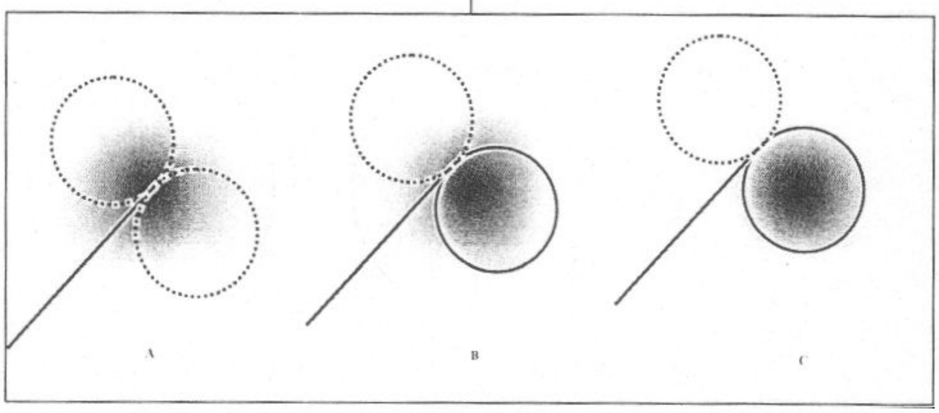


Figure 3: Which Way To Turn. The further the entry courseline is from a diameter, the greater the cost of a turn the wrong way. A) No need to worry — both ways are wrong, and there is no way to distinguish. B) Right turn is favored, but unless the right wing lifts prior to the turn, the pilot does not know this. C) The sufficiently lucky or skillful pilot can perfectly tome the turn, get the direction right, and be centered almost immediately. In reality, the very best pilots can do this perhaps once in ten thermals.

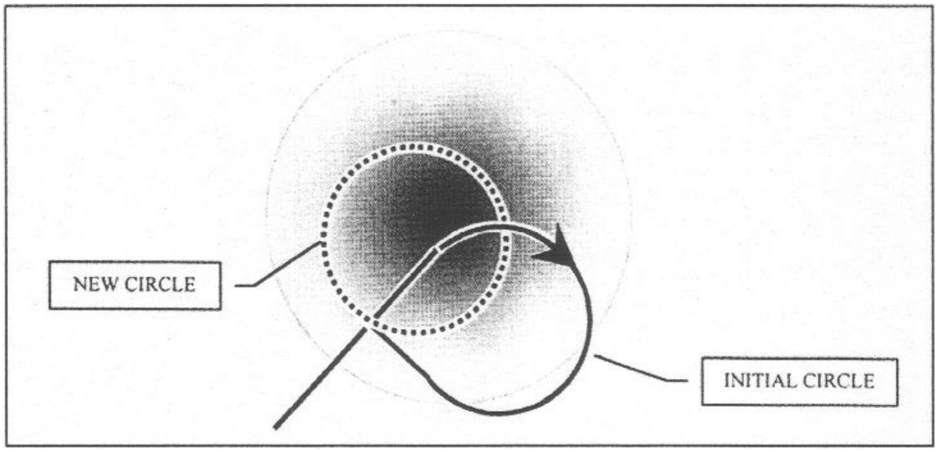


Figure 4: The Initial correction. With the vario heading down for more than half the initial circle it's time for the correction: As the glider comes around to a heading 90° to the entry heading, roll out, then roll back in again, moving the circle in the direction of the lift. This only works if the entry into the turn is reasonably well timed.

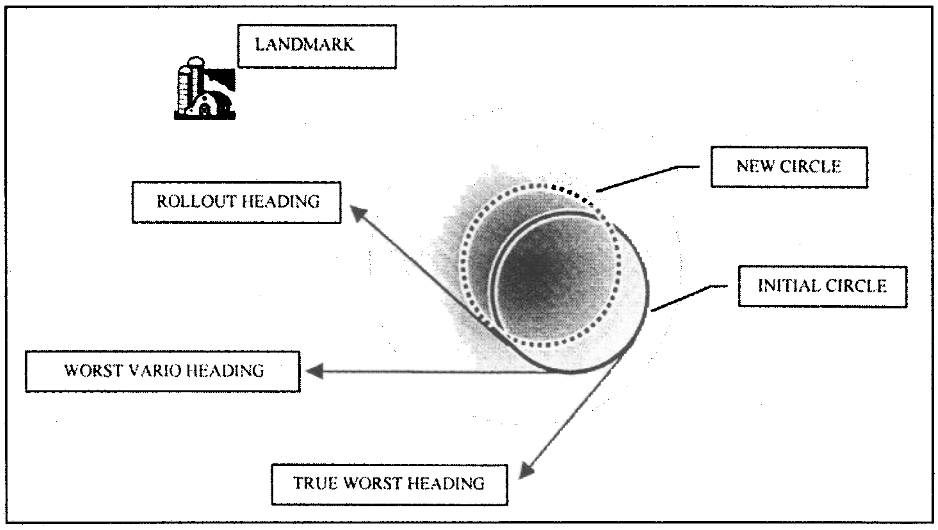


Figure 5: Centering. In a 45° bank, a 2 second vario lag is 1/8 of a circle, or 45°. This is easy to judge. 45° after the worst vario reading is the time to rollout. This, too, is easy to judge since the bisector of the wing and the fuselage axis is 45° from the worst vario heading. At the worst vario heading, find a landmark on this bisector.

as the vario promptly heads south, more or less as soon as the turn is started in what had been 4 kts up. In all three cases – turning too soon, too late, or at the perfect time - a correction will be needed.

Entering on a Chord

It's more likely that the thermal will be entered on a chord (Figure 3b,c), and in this case there is a right way and a wrong way to turn. The good news is that there is some chance that the glider, birds, or even debris will provide a clue.

The chance of turning the wrong way when entering a thermal on a chord is 50%. Add to this the certainty of turning the wrong way when entering on a diameter, and it is clear that in the absence of additional clues, it's likely that the turn into the thermal will be in the wrong direction. It helps to know that geometry and probability, not caprice, account for this.

Climbing in Thermals

There are many ways to center a thermal. What follows is a basic technique that works well and is easy to learn. It has been described by many others.[3,4] Plan to practice and master this basic technique, then experiment with other centering methods.

The Initial Correction

Only rarely will there be constant lift in the first circle. Far more often the vario will at some point (not necessarily immediately on entering the turn) indicate decreasing lift, or even sink, and will continue to do so for a good fraction of the circle. When this happens, and when the turn has been timed correctly, the correction can be made by waiting until the glider has come around to right angles to the entry direction, rolling out, then rolling back in again. This will move the glider closer to the center of the lift as is shown in Figure 4. The skill lies in knowing the distance to fly before rolling back in again. A good starting point is to increase the distance flown after rolling out in proportion to the time spent in poor lift. It is better to err on the side of too small a correction, since it is easy to repeat the maneuver the next time around.

Centering

It is helpful to translate seconds of vario lag to a fraction of a typical circle. I'm assuming that a circle takes about 16 seconds (45° bank), and that the vario lag is 2 seconds - 1/8 of a circle. You should check your vario's lag.

When the glider is established in a circle but not yet centered, the correction is simple: 1/4 of a turn after the actual point of worst lift, smoothly roll to wings level, then back to the original bank. Allowing 1/8 of a turn for vario lag, the correction should be applied 1/8 of a turn after the indicated point of worst lift.

This may or may not center the thermal, but it will move the glider towards the center of the lift. The correction should be repeated during each circle until a more-or-less steady climb is indicated.

It is easy to establish the heading on which to roll out: At the indicated point of worst lift look for a feature on the ground aligned with the bisector of the low wing and the fuselage axis, then roll out heading toward that feature. This procedure is shown in Figure 5.

There is no need to wait until the second time around the circle to do this. The initial correction can (and should) also be made with the aid of the variometer and exactly the same considerations apply: 1/8 of the circle following the point of indicated worst lift, roll out for about a second (~ 80 ft). If everything has gone according to plan, the glider will be on a heading 270° from its entry heading, it will be accelerating vertically ("surge"), and the vario will start to head up. Roll back in again. Repeat as necessary. Small errors in the timing are not important – provided they are less than

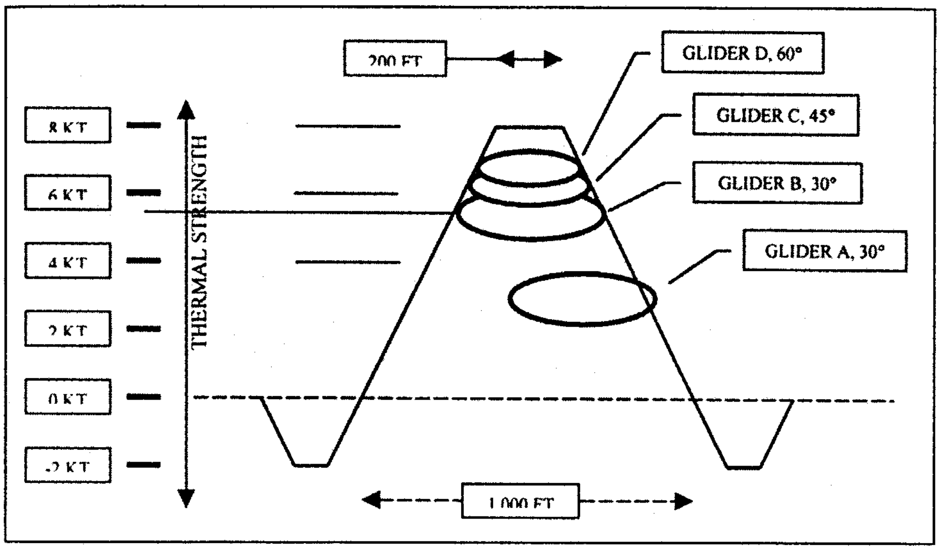


Figure 6: Optimizing The Climb. Glider A is neither centered nor optimized. Glider B, with the same size circle is centered and climbing better. Glider C has a smaller, centered circle and is able to use better air. Glider D is in even better air, but the bank is so steep that sink rate is now an issue.

about 20 degrees, the circle will still be shifted in the right direction.

Optimizing

Once centered, it remains to optimize the lift, and to keep centered. Both require constant attention and work. The pilot who can talk on the radio while climbing is not working hard enough. Figure 6 illustrates the potential for optimizing the lift. For reference, Glider A is shown neither centered nor optimized. Glider B is centered, but the circle diameter keeps the glider in 5-6 kt air. Glider C, with a smaller circle, may be able to climb better since only a relatively small increase in sink rate is associated with the smaller circle in 6-7 kt air. Glider D is likely to find that the increased sink rate (which about doubles in going from a 45° to a 60° bank) cancels the advantage of being in better air. As the glider climbs, the diameter of the thermal typically increases, and the circle should be adjusted accordingly.

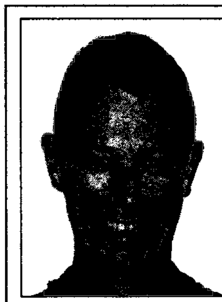
Conclusion

It's really not very difficult to find, center and optimize lift if a few simple rules are followed. When they are, and with a little practice, it is possible to stay aloft for as long as there is lift, and to fly as far as the lift will allow.

It is also possible to fly for thousands of hours, and tens of thousands of cross country miles, and still be learning, so great are the challenges and opportunities of soaring.

Notes:

1. *Just a Little Faster, Please, J. Cochrane, Soaring, Sept. 2000.*
2. *Cross-Country Soaring, H. Reichmann, SSA.*
3. *The Simple Science of Flight – From Insects to Jumbo Jets, H. Tennekes. MIT Press, 1992.*
4. *Gliding, D. Piggott, A.C. Black, 1986.*
5. *Soaring Across Country, W. Scull, Pelham Books, 1986.*
6. *Meteorology and Flight – A Pilot's Guide to the Weather, Tom Bradbury, A.C. Black, 1989.*



About the author: Richard Kellerman lives and flies in Southeastern Pennsylvania, between the westernmost reach of the Bermuda High and the Appalachian Mountains. He manages to fly his ASW-27 for about 120 hours a year. He also tows gliders and for the past few years has presided over the weather, good and bad, at contests at Mifflin County Airport in central Pennsylvania.

SOME COMMON BEGINNER'S MISTAKES

- Failure to fly round circles (constant airspeed and bank angle).
- Circling on any blip from the vario, without a good indication of real lift.
- Circling on the first indication of lift, rather than trying to time the first turn properly.
- Circling in huge 15-degree banked turns while steeply-banked gliders climb better.
- Failure to make a small correction with each circle until a thermal is centered.
- Failure to spot birds, developing cumulus clouds, and climbing gliders.
- Circling in 2-knot lift while nearby gliders climb at 5 knots.
- Chasing every circling glider, without watching to see if they're actually climbing.
- Trying to get the last 200' of climb from a thermal whose strength has dropped by half.
- Staring at instruments rather than looking outside.
- Settling for weak climbs on a day when strong thermals are available.
- Trying to spend all day within 500' of cloudbase; assuming there's no way to climb from 2000' agl (even as gliders off tow do so all day long).
- Blaming the glider for the pilot's shortcomings; assuming that only expensive gliders can climb well.
- Trying to learn thermaling with an inadequate vario (no audio or TE compensation).
- Assuming that expensive instruments are the key to successful thermaling.
- Failure to master the basics of thermaling before trying special techniques.
- Failure to experiment with other thermaling techniques once the basics are mastered.