Thermals - Simple Model

- Rising Column of Air
- Warmer than Surrounding Ambient Air
- Surrounding Air Sinking or Stable
- Visible Examples
  - Smoke Column / Steam Plume
  - Whirlwind
  - Dust Devil
  - Tornado (Extreme Case)
- Strongest Lift at Center of Column
- Lift Weakens as Radial Distance from Center Increases
- Turbulent Chop at Interface of Lift and Sink
- May be a Bubble of Rising Air
- May Have Horizontal and Vertical Movement

Cumulus Clouds Mark Thermal Lift

- Sharp Outline - Building
- Indistinct Outline - Dissipating
- Concave Upward Base
- Best Lift
  - Under Darkest Part of Upward Concave Cloud Base
  - Under Upwind Third of Cloud
  - Near Sunny Side of Cloud

Wispy Clouds

- Developing Clouds - Growing
- Dissipating Clouds - Shrinking or Disappearing

Soaring Birds Mark Thermals

- Good Markers
  - White Pelicans
  - Golden Eagles
  - Red Tailed Hawks
  - Vultures (at low altitudes AGL)
- Poor Markers
  - Seagulls
  - Birds Flapping Wings

Books
Thermals
The Soaring Engine - Dale

Thermaling
- Use Audio Variometer
- Constant Airspeed Slightly Above Minimum Sink Speed / Safe Stall Margin
  - Constant Nose Attitude = Constant Airspeed
- Constant Airspeed Lets Variometers Show What Is Happening Outside
- Vary Bank Angle
  - Shallower Bank when Lift is Increasing
  - Steeper Bank when Lift Is Decreasing or in Sink
- Slip - Don't Skid
  - Tail of Yaw String Toward High Wing - Safe
  - Tail of Yaw String Toward Ground - Beware

Thermal Entry
- Turn Toward Lifted Wing
- 360 Turn If Lift Increases
- 270 Turn If Lift Decreases

Center Thermal
- Mentally Picture Location Of Lift
- Use Ground References
- Use Cloud References
- Use Sun References
- Make Relative Position References
- Compensate for Wind Effects
- Try to Get High Constant Rate of Climb on Variometer
- Try to Attain Highest Average Rate of Climb

Gaggles
- First Glider in Thermal Determines Direction to Circle
  - May Have Local or Contest Rule for Left Turns Near Airport and Turnpoints
- Circle Same Direction as Gliders Already in Thermal
- Do Not Endanger Other Gliders
- Maintain Airspeed with Safe Margin Above Stall
- Know Where Other Gliders Are
- Keep Other Gliders Near Same Altitude in Sight
- Avoid Flying in Blind Areas of Other Gliders Near Same Altitude
- Communicate with Other Gliders in Gaggle
  - Hand Waves
  - Radio
- Use Other Gliders as Variometers

Top of Useful Thermal
- Cloudbase
- Inversion
- Weakening Lift
- Through Out

Exiting Thermals
- Do Not Endanger Other Gliders in Gaggle
- Increase Airspeed for Flight Through Sink
- Departure from Tangent of Circle
  - Safer If Near Other Gliders
- Departure through Center of Circle
  - Only If Alone

BUBBLES OR COLUMNS

Some thoughts on the shape of thermals and how they show up when cumulus clouds develop

Nearly half a century ago the "bubble the-
ıry" of convection was introduced to explain the ;hape of thermals. It was not universally ac- :epted and still produces protests from some pi- ɔls. The idea was disputed by some meteor- ılogists too who preferred the idea of a "thermal ılume", which is another way of describing the hermal as a column.

The bubble theory arose from studies of a vater tank in which a dense salt solution (marked vith a white precipitate) was allowed to sink hrough the less dense pure water. The differ- ɛnce in densities produced much the same mo- ions as in a thermal which rises through a colder lenser atmosphere. The time lapse photos ooked remarkably like real cumulus clouds vhen the picture was inverted so that the salt :loud appeared to rise.

This picture of a thermal bubble appeared ɔartly because the initial watery thermal was re- eased as a cup shaped mass in the first place. However, the majority of real thermals grow from ı wide area above which the warm air exists ini- ially as a shallow layer. As part of this air rises it orms a tall column which is fed by an inflow of surface air. On calm days windsocks often re- eal where a thermal has lifted off.

The bubble shape first appears at the top of he column. This column probably remains in- act until the supply of warm air is cut off. Thus hermals can be both columns and bubbles, but ..y usually begin as a column and develop the ..le circulation at the top.

Stubble fire illustration

Photo A shows stubble fire smoke forming a :olumn which changed into a bubble shape at he top where a small cumulus formed. Although he stubble fire supplies more concentrated heat han is available for most thermals the shape of he lift is probably similar. While the fire contin- ɹes the smoky column has fairly parallel sides Nhen the fire dies out the base of the column ıarrows and breaks off; the remaining smoke is łrawn up into the bubble and soon spreads out ınder the inversion.

Simple thermal structure

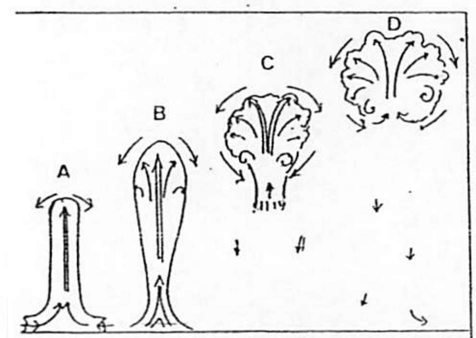


Fig 1. The sequence A to D shows how a ther- mal column can evolve from a layer of warm 'ace air. Exhaustion of the supply first ..uces a neck in the column. When this ɔreaks the bubble structure takes over.

It seems likely that many thermals have the ;ame structure as in Fig 1. At A the column has ust begun and the top is pushing the air aside

Photo A. Stubble fire showing parallel sides to the smoke column until it reaches cloud- base.

initiating the outflow of a bubble. At B the col- umn broadens at the top and the edges are de- veloping the outward curving motion typical of a forming bubble. The column also develops a neck near the base where the air is accelerating up. In C the supply of warm surface air has ceased and the column is drawn up into the ex- panding bubble. The final stage is shown in D. It is likely that the bubble, which is expanding as it draws in cooler air, loses so much heat that only its momentum keeps it still rising.

Many bubbles come to rest soon after stage D but in very unstable air a few continue to shoot up leaving a trail like a rocket. Wind shear even- tually blows them to one side leaving a slanting spur to evaporate in the dry air

Vortex rings

The extreme case of a bubble is the vortex ring. A fully formed natural vortex ring is proba- bly rare. It can be observed when the thermal starts as an explosion, for example when a petrol tank blows up after an aircraft crash. Then the hot air is hurled up instead of rising naturally and instead of a column you get a vortex ring. The column forms later when the system settles down into a long lasting fire. Old fashioned steam locomotives occasionally puffed out vortex rings from their funnels. Early atomic bomb tests also produced vortex rings.

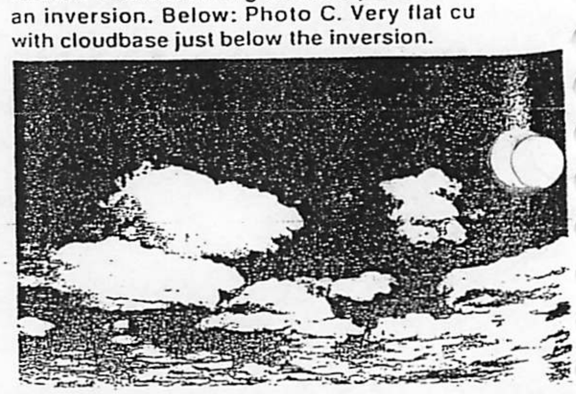
There is a tendency for vortex ring structure to appear in strong thermals. It shows up in grow- ing cumulus. The core of the thermal rises at about twice the speed of the summit. The upper edges of the cloud move outwards from the axis of lift and slow down. Fig 2 A shows how the pro- file of a growing thermal expands with small bulges moving outwards as the cloud ascends. Seen through a theodolite these edges sink rel- ative to the summit. Some actually are in sink. This sink can often be found just before you reach a thermal. Thus a thermal bubble contains the initial stages of a vortex ring but it seldom develops fully.

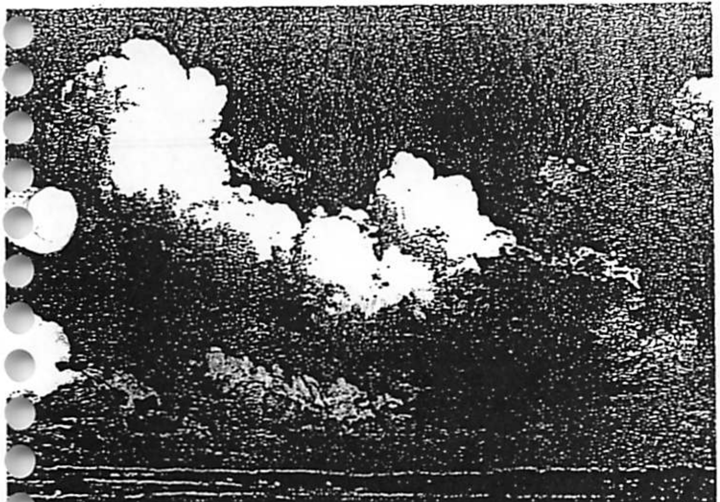
Fig 2 B shows a true vortex ring puffed from a funnel. It is given a boost before it emerges and friction from the inside of the funnel helps create the spin which keeps the ring intact as it rises. Vortex rings do not all rise like this. Skillful pipe smokers can emit them at any angle

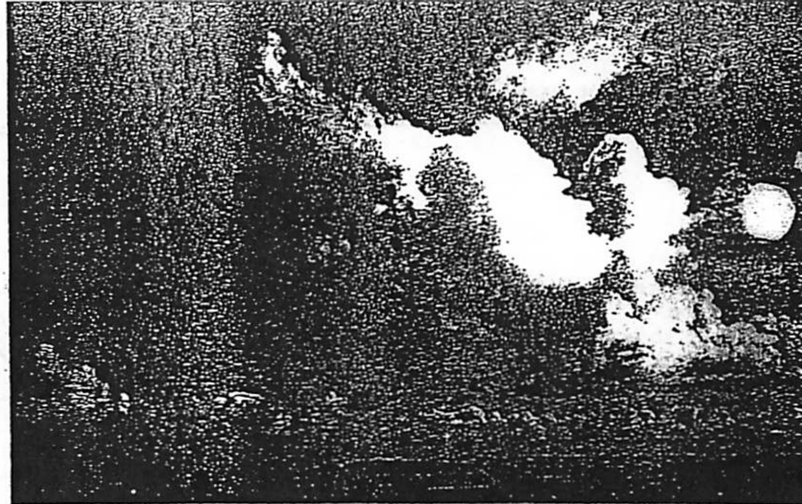
Some visual indications of thermal structure

Blue thermals remain essentially invisible until they pass the condensation level. Sometimes they carry up dust which forms a visible haze cap which shows up well when viewed through

Above: Photo B. Very short lived puff of cu formed where a strong thermal penetrated an inversion. Below: Photo C. Very flat cu with cloudbase just below the inversion.

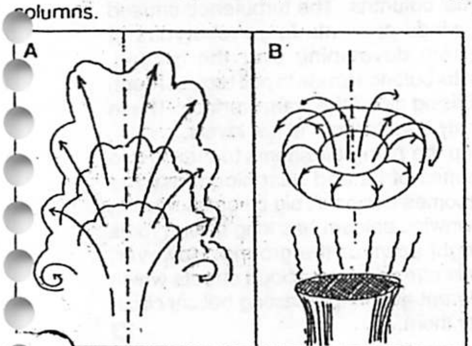






Left: Photo E. Wind shear effect. Old unsupported bubble blown off to left, new active bubble forming on right. Right: Photo F. Decay of an unsupported bubble (left) leaving only cloud tendril where the moist core had been.

polaroid glasses. Lasers have been used to track the dust in a rising blue thermal. An American helicopter pilot equipped with infra-red goggles said desert thermals appeared as snaky columns.



Air motions in a rising thermal showing A how features move outward from the main axis. In B the bubble is hurled upwards (by an explosion or from a funnel) and a vortex ring can form.

Thermals start to rise because they are warmer and lighter than their environment but once in motion they develop a momentum which can carry them up even when they have lost their excess temperature. A strong inversion halts most thermals within a few hundred feet. Little puffs of cloud occasionally mark the peak of a thermal which penetrates the inversion. These puffs appear when the condensation level is above the inversion. They are formed by an overshooting thermal thrusting into the dry stable air aloft. These puffs are extremely short lived and do not look much like bubbles. Their motion is chiefly horizontal showing that the upward momentum of the rising column has been diverted sideways. Photo B shows such a puff rising into a wind shear which pulled the tendrils of cloud over towards the left. It was one of a number of very brief puffs formed in strong thermals over a sun facing slope. They were the only clouds on an otherwise blue day.

Photo D. Deep convection. The thermal column under the main dome had ceased and there is no flat base. New lift likely to be developing further to the right.

When the condensation level is just below the inversion one gets typical shallow cumulus (Photo C). Any bubble which had formed lower down is flattened out under the inversion. In calm conditions one can see the elements of cloud moving out from the core in different directions before evaporating. A good time to watch this is when lying on the ground at the launch point waiting for one's turn. Strong thermals produce marked horizontal movements in several opposing directions where the air is deflected by the inversion. Small hook shapes may appear if the clouds are deeper. These are caused by the wind shear trying to roll up the cloud. I have seen a complete hoop formed this way but it evaporated too rapidly for a photo.

In less stable air when the inversion is high above the condensation level clouds grow large enough to show the structure of the thermal more clearly. While the thermal column lasts the cloud base is usually flat and well defined. When the thermal column ends the cloudbase gradually loses its sharpness but the top may go on rising

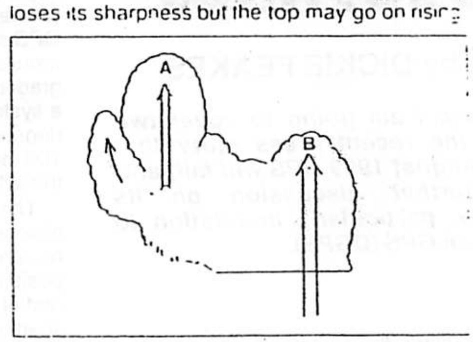
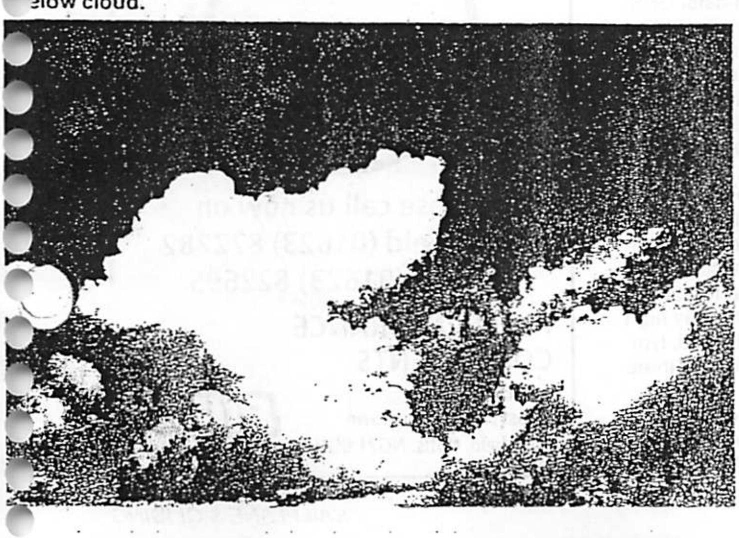
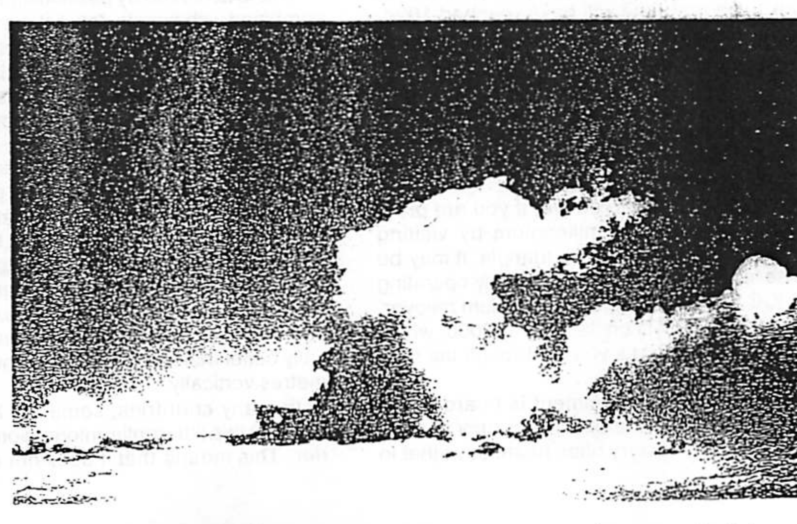


Fig 3. Simplified cloud outlines to accompany photo D. Thermal A is turning into a bubble with no supporting column below but the new cell B shows where useful lift occurs. ➡

Left: Photo G. A three bubble cloud; oldest top right, youngest just starting bottom left. Right: Photo H. Decay due to ending of thermal column below cloud.





An active bubble is marked by a clearly defined dome shaped top.

Rising domes show the outline of the thermal bubble for some time after it has lost its supporting column. At this stage it is probably a true bubble very like the laboratory model. There is seldom any useful lift below such a bubble. One has to move upwind to locate a fresh column of lift where the next thermal enters. Fig 3 is a simplification of photo D which illustrates this effect. The original thermal is at A where it is still rising with a well formed dome but the decayed cloudbase beneath it shows there is no longer a column of lift entering the cloud directly under the dome. The new thermal at B is more recent and had lift below cloudbase at that time.

Wind shear pushes dying bubbles aside

A long lasting cumulus may be seen to have formed from several columns which broke off into individual bubbles of cloud. As the supporting column dies the dome shaped bubble goes on rising for a time but is apt to be drifted sideways by any wind shear. Photo E shows the old bubble blown aside to the left and a new cell forming to the right. Photo F illustrates the fate of such unsupported bubbles. The first sign of decay is a loss of definition at the cloud edge.

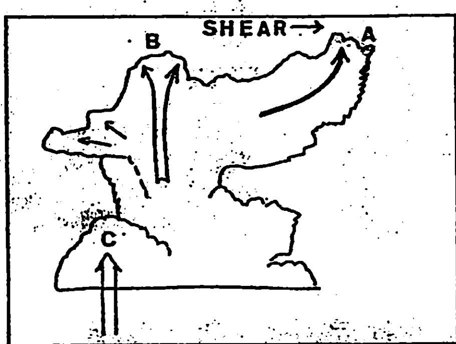


Fig 4. Cloud outlines of a three cell cumulus in a weak wind shear from right to left. Cell A is dying and being blown sideways. Cell B is reaching its maximum height but the incoming lift is being transferred to the small cell C.

Active domes often have many smaller bulges growing out of them. When a dome decays the outline becomes flabby. The edges are first to be eroded by mixing with the surrounding dry air. The old core is last to go. Photo F shows the last shreds of a dead thermal blowing off to the left.

Photos G and H show the collapse of bubbles in a cloud which lost its feeder column of lift underneath. The wind shear was from right to left. Fig 4 shows how the cloud in G evolved. The first and oldest bubble at A had already begun to lose shape on the right, a slightly younger bubble B appears at top left while a new and much smaller cell C is forming bottom left. Unfortunately the feeder column was dying and the third cell C did not grow much larger. Photo H shows the result a few minutes later. Some much smaller cu had by then begun to form well to the left of the original cloud.

Effect of strong winds

Long lasting thermal columns form best in very light winds. Strong winds tend to break up most thermal columns. The turbulence caused by strong winds prevents large reservoirs of warm air from developing over the ground. Instead the turbulence tends to pull broken rough bubbles of rising air off the warm surface. These are extremely hard to work at low levels.

Higher up the rising air seems to merge into larger volumes of lift and near cloudbase the soaring becomes easier. A big cumulus moving quickly downwind seldom has long lasting roots reaching right down to the ground. However, strong winds often produce cloud streets which have a different and longer lasting helical circulation under them.

GPS JOTTINGS

Edited by DICKIE FEAKES

This issue I am going to cover two topics; the recent press story that during August 1999 GPS will fail; and some further discussion on its accuracy, particularly in relation to differential GPS (DGPS).

A few months ago a widely published press story forecast that during August 1999 the GPS system would fail. The basis behind the story is that GPS uses weeks to keep track of time, with week 1 being the time that the first satellite was placed in orbit. During August 1999, the week count since that time will have reached 1024, which in computer binary notation is the highest that the GPS system can apparently cope with. Hence the suggestion was when the week count reached this figure, the system would crash. In reality, the designers of GPS software have long realised this limitation and taken steps to prevent any disaster.

Notwithstanding the above, if you are planning to celebrate the millennium by visiting Australia to do your 1000km triangle, it may be unwise to rely on the system correctly operating ur IGC approved logger at millenium rollover, 01hrs UTC (GMT) on January 1, 2000, which will occur just about as you go through the start gate Australian local time...

Much uninformed comment is heard in the bazaars regarding the basic accuracy of GPS and one particular story often heard says that in gliding we will all be using DGPS within a year! As outlined in a earlier "GPS Jottings" (June issue, p170), the basic accuracy of the GPS system to which we have regular access is around ten metres. This level of accuracy is degraded artificially by the US military by means of a system called Selective Availability (S/A). S/A degrades the system accuracy to a maximum of 100 metres by altering the clock timing on which the sytem relies.

The effect of S/A can easily be seen by coupling a logger to a static GPS and analysing the resulting trace. It will be seen that the apparent position follows a geometric pattern over a period of some hours rather than a totally random scatter. Furthermore, if two systems are set up side by side, the pattern will be identical in both units. This fact is used by DGPS to calculate a correction at any given time so that the position error due to the incorrect timing signal can be corrected.

This is achieved by positioning a master GPS, combined with simple data link transmitter, at an accurately surveyed position. Every second, this master GPS compares the calculated GPS position with its known accurate position and produces an position error. This position error is then transmitted by the datalink, together with data which identifies which satellites (or constellation) were used to calculate the position.

A GPS coupled to a suitable datalink receiver uses this information first to select the same constellation with which to calculate its position, and then uses the received error signal to correct that position. The result is that extremely high degrees of accuracy can now be achieved, typically better than one metre horizontally and three metres vertically.

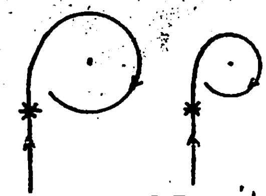
In many countries, some FM broadcasters transmit this differential information on a sub carrier. This means that it does not interfere with the normal radio programme being broadcast but can be decoded by a suitable receiver. In the UK, Classic FM already broadcasts differential information and by paying a licence fee, it is possible to extract this DGPS information and feed it to your handheld or glider mounted GPS receiver to give it a high degree of accuracy.

However, it is difficult to see why in gliding, even in World Championships, accuracies of this order are required. The straightforward S/A signal is mind bendingly accurate for most of us, and if the US miltary turn off the S/A, as they have indicated they might, it is difficult to see why gliding needs to get involved in the complexities of DGPS.

DEREK's NOTES ON THERMALLING

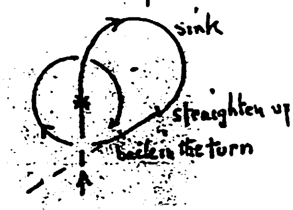
The aim is always to get into the lift quickly with a minimum risk of losing it.

Turn immediately if you feel a good surge and the vario needle is rising. The first turn should always be tight.

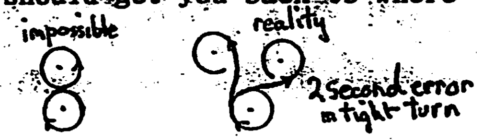


Turn tightly (steep bank, low speed) to keep close to that area.

If the rate of climb continues to rise, keep turning.
If it drops after the turn is started, turn a little less than 270 degrees and then bring the wings level for a moment before continuing the turn. This should get you back to where you felt the lift.



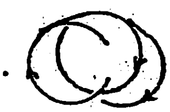
Never reverse the turn.



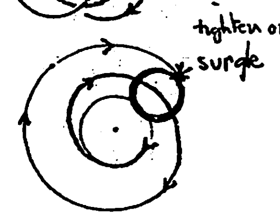
Always make corrections positively using all the rate of roll - use full aileron and rudder to straighten up and go back into the turn.

Never straighten up and wait for the lift to improve. Remember that a fast vario will always show an improvement on straightening up.

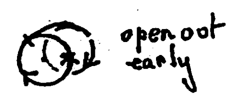
Move a little each circle and judge the overall result, good or bad.



When apparently well centered but in weak lift, gradually widen the turn to cover a larger area. If a surge is felt, immediately pull into a very steep turn to center on it. Only use this method if you can make a significant increase in the angle of bank. Steepening a steep turn does not move the circle much and can result in losing control.

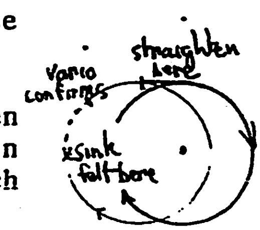


If a surge is felt while turning steeply, continue the turn and open out early towards the position of the surge.



Only keep turning steeply if the rate of climb is good. Otherwise widen the turn again to find another surge.

If during a turn sink is felt, continue about 90 degrees and then open out to move away from it. Never continue circling half in and half out of the lift without making a small move on each turn.



Never speed up in sink when turning.

Turning at 20 - 25 degrees per second, corrections have to be made very early and quickly to move where you want to go. As soon as the wings are level go immediately back into the turn. Even this moves your circle quite a long way in a modern glider.

Practise very steep turns at low speed so that you can turn with well banked turns confidently. You must know the characteristics of your glider when it stalls in turns, most are virtually impossible to stall in turns of more than about 35 degrees of bank.

THERMALING TECHNIQUES

by Phil Petmecky

Probably the most difficult thing to teach a student, or for a rated pilot to learn, is how to get the most out of a thermal. Most students have their hands full just flying the glider. Only advanced students can begin to grasp the fundamentals of basic thermaling techniques. Frequently, private pilots have certain ways (habits) they think works for them and are unable, or unwilling to learn new and better methods.

Have you ever been happily climbing a thermal and feeling you had really nailed it only to have a lower performance glider come in below you and quickly climb above you? This can drive a pilot to drink, not to mention a severe case of embarrassment. This happened to me all the time when I first started soaring. I was a *transition* pilot and got my glider rating without being taught how to thermal successfully. I read all I could find on the subject, talked to all the hot shots, and practiced, practiced and practiced some more. Now, after more than 10,000 glider flights, I think that I'm finally beginning to understand some of the basic principles of good thermaling. Following are some of my ideas on how to thermal successfully.

Common errors made when thermaling are:

1. Poor speed control
2. Bank angle too shallow
3. Corrections too late or incorrect
4. Fixating on the vario

In a contest or during a long badge flight, good thermaling is a must. Many pilots get in bad habits when flying locally by being satisfied with a fair rate of climb. You must constantly try and get the most out of any thermal you are working. You must also leave it at the correct time and move on down course. How many times have you worked several 3-4 knot thermals and flown to another cloud, losing only a few hundred feet and stopped to work a 2 knotter? This practice should be avoided! Continue through a weak thermal, only slowing a little in the weak lift and continue to search for another good one. Only work a weak thermal if you are getting low and in danger of landing out! Of course, on weak days you should try and work weak thermals to improve your thermaling technique.

Lay out a good 50 to 100 km task around your home field. Fly this task every time the lift is enough to insure a good chance of the task being completed. Time yourself and compute your average speed when the task is finished. Carry a barograph, if available, and analyze the trace at the end of the day. Count the number of times you stopped to thermal. You will probably see several climbs in weak lift for only a few hundred feet. These are most often errors, and cost time. At first you will see a lot of small climbs and short periods of cruise, sort of like a fine saw tooth. Later, you will see longer periods of cruise and sharper (and fewer) climbs. Your speed will also improve. Make a list of errors (poor decisions) made and try and reduce the count on your next flight.

When instructing students in how to thermal I like to tell them that there is ONE time they should shallow their bank and TWO times they should steepen their bank. Shallow the bank, slightly, if the vario is rising. Steepen the bank, slightly, if the vario is falling. These corrections will cause the glider to center itself in the thermal. Steepen the bank, quickly and much steeper, if the vario is near the top of the best lift you think is possible.

Get a good picture in your mind of where you think the center of the thermal is located. Anticipate when you think you are going to turn back into stronger lift and shallow your bank quickly just as the vario starts to rise. This is very important; pilots frequently delay this correction until the vario has risen substantially. Remember, there is some delay in the fastest vario. You must be "thinking ahead" of it. Late corrections will take you out of the best part of the lift. Shallow your bank at the first rise of the vario and hold at the new bank angle for a couple of seconds and then quickly steepen the bank, don't wait for the vario to start to drop. If you perform the correction properly you will be quickly rewarded with a faster climb rate. For example, you may be circling at an average of say two knots, getting four on one side and near zero on the other. When the vario first begins its climb from zero knots, shallow the bank. The vario may only have climbed to two knots when you steepen the bank. If the correction is properly made, e rate will continue to increase as you steepen the bank and stay at the higher value (say 3 knots) throughout the turn. you have obtained a fairly solid of climb around a full circle, try and make the circle smaller with a steeper bank for a higher average rate of climb.

The only times you should ever thermal above minimum sink speed are if you are working a very turbulent thermal, or are very low (less than 1500 feet AGL). Frequently, you will find that a speed lower than minimum sink will actually give a faster climb because your circles are smaller.

Throughout the climb it is very important to maintain your airspeed at the proper value. When you are circling off-center in a thermal you will experience changes in airspeed with NO change in the position of your controls. When turning into STRONGER lift, the airspeed will show a slight increase. You should add just enough additional back pressure to maintain the correct airspeed as you make your bank correction—a shallowing of the bank in this case. The reverse is true when turning into weaker lift. Learn to use your ears to help with airspeed control. Slight changes in airspeed can easily be heard by a pilot with a good ear.

ne error pilots frequently make n first entering a thermal is that they ease the stick FORWARD when first banking, even though they were at the proper airspeed for thermaling, or even slightly faster than best thermaling speed. I guess that they are afraid of stalling in the turn. They will then (usually) add back pressure as the turn continues to slow to thermaling speed. This makes the first turn wider than desired and probably costs 25 to 50 feet of climb in the first circle!

Once you enter a thermal be sure and retrim for proper speed and put your flaps in the correct position for thermaling. In most cases this will be full back on the trim control and one or two notches of flaps.

Another frequent error at thermal entry is failure to clear the turn. This happens even in gliders with audio varios. Never fix your attention solely on the vario. Clear before, and as the turn is initiated, or be sure you are wearing a good parachute! You must also continue to clear the area while you are thermaling.

Occasionally I like to get in a thermal another glider and fly position on —not trying to thermal myself. This way I can see if he is making the same corrections I would make if thermaling alone. I also spend a lot of time in the back seat of trainers observing pilots thermaling. This is easy to do in the local area except when getting low and the "student" isn't doing a good job—or I think I could do a little better. I tried to let some of my students do some of the thermaling when we took our Lark to Hobbs, New Mexico a few years ago to fly in a contest. This only lasted a few minutes and I ended up doing all of the thermaling after we started a task. My co-pilots were actually thermaling fairly well, but not good enough to make me comfortable.

Most glider pilots also like to thermal in one direction only. When forced to thermal in the "wrong" direction they do a poor job. Two suggestions: If you are one of the many who prefer one direction, force yourself to thermal in the opposite direction when flying locally. Eventually you will be able to go both directions equally well. One reason some pilots always seem to turn to the right while thermaling is that this is the direction they turn in the first thermal as they release from tow. When approaching a good looking cloud make sure you aren't holding the stick tightly. Relax. A light grasp on the stick will allow you to "feel" the thermal as you enter. One wing will almost always rise a little. This indicates that the thermal is stronger on the high wing side and you should turn in that direction.

After deciding which way to turn you must then decide when to turn. This is a more difficult question. Try and penetrate into the thermal until the vario either starts to fall or shows a very good rate of climb near the top you have found on that particular day. Enter the first turn with a sharp roll to about 45 degrees of bank.

One factor that effects when to turn is the direction of the wind. If flying into the wind delay the turn more than if flying with the wind. If you are coming into a thermal below a cloud you should consider the position under the clouds where you found the last few thermals. If the wind is light the position under the clouds can vary a lot. If the wind is a little stronger look on the upwind or sun side of the cloud. If you can see a concave high spot in the bottom of the cloud you can bet that's where the best lift is.

I do feel that certain gliders climb better thermaling in one direction. I think our Grob and K-8 do better turning to the right, while my LS-3 feels better to the left. I reason that this is due to a slight difference in rigging of the glider, or maybe one wing is heavier than the other. This is probably a figment of my imagination, but I will always turn in my preferred direction if I don't feel good wing lift in the other direction.

When I first started flying contests I was a right hand thermaler. You are required to thermal to the left within five miles of the start gate and all turnpoints in contests. This caused me a great deal of difficulty until I learned to thermal to the left. I almost landed on several occasions and had a difficult time climbing high enough to make a run through the start gate.

I also feel that some gliders climb better if the yaw string is kept slightly (5 degrees) to the outside of the turn. You will have to experiment with this on the glider(s) you fly regularly.

I think that it is best for students first learning to thermal to fly gliders with an uncompensated vario. It is, of course, easier to thermal with a good total energy vario because climbs, or descents caused by poor speed control are cancelled out of the vario. It is my feeling this leads to poor thermaling techniques because the students never learn good speed control. Thermaling with an uncompensated vario forces better speed control. If the speed is not smooth, the pilot is unable to climb and will quickly lose the thermal.

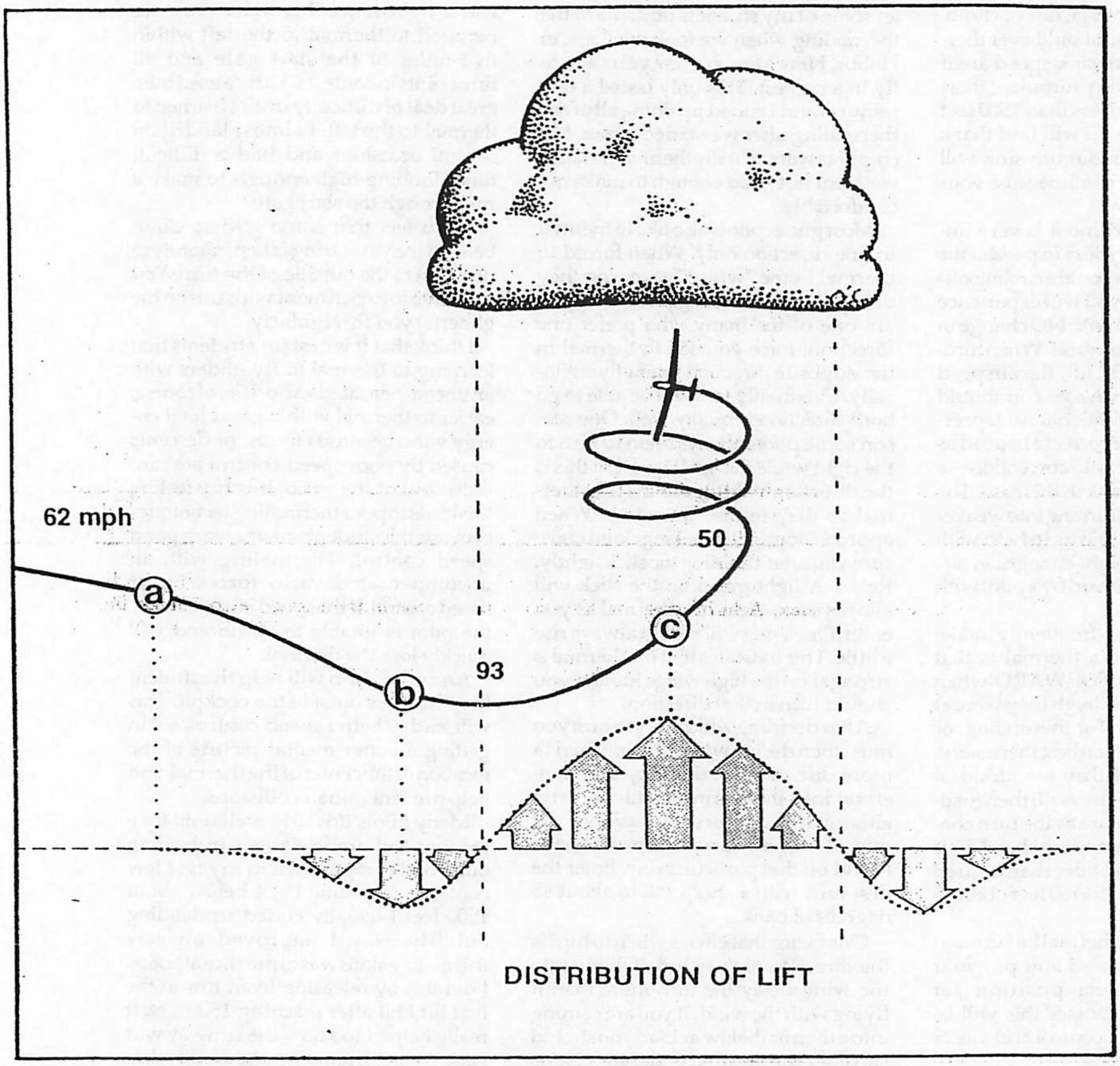
An audio vario will help the student keep his eyes outside the cockpit. This will lead to better speed control, aid in getting a better mental picture of the location of the center of the thermal, and help prevent midair collisions.

Many pilots do fairly well until they get low and are in danger of landing out. I had this problem in my first few contests. Any time I got below about 1500 feet I usually ended up landing out. The way I improved my low thermaling skills was to practice at home. I did this by releasing from tow in the first lift I hit after reaching 1500 feet. It really helped to know the runway was near. At first I frequently landed back at the airport and had to pay for another tow. As I improved I moved the release altitude down to 1000 feet.

Another thing I did that helped was to launch early (and often), while most of the local group was still waiting for the first cu's to pop. At the end of the day, I would try to be the last to land and work the last 1/2 knot of lift I could find. This really smooths out your thermaling a great deal!

There is no substitute for practice. I hope some of my ideas are a help to you. ■

Fig 50: Entering a Thermal



Thermals are usually surrounded by sink. The red arrows show lift and sink.

a Here, the pilot enters a zone of increasing sink. He speeds up to the recommended speed-to-fly.

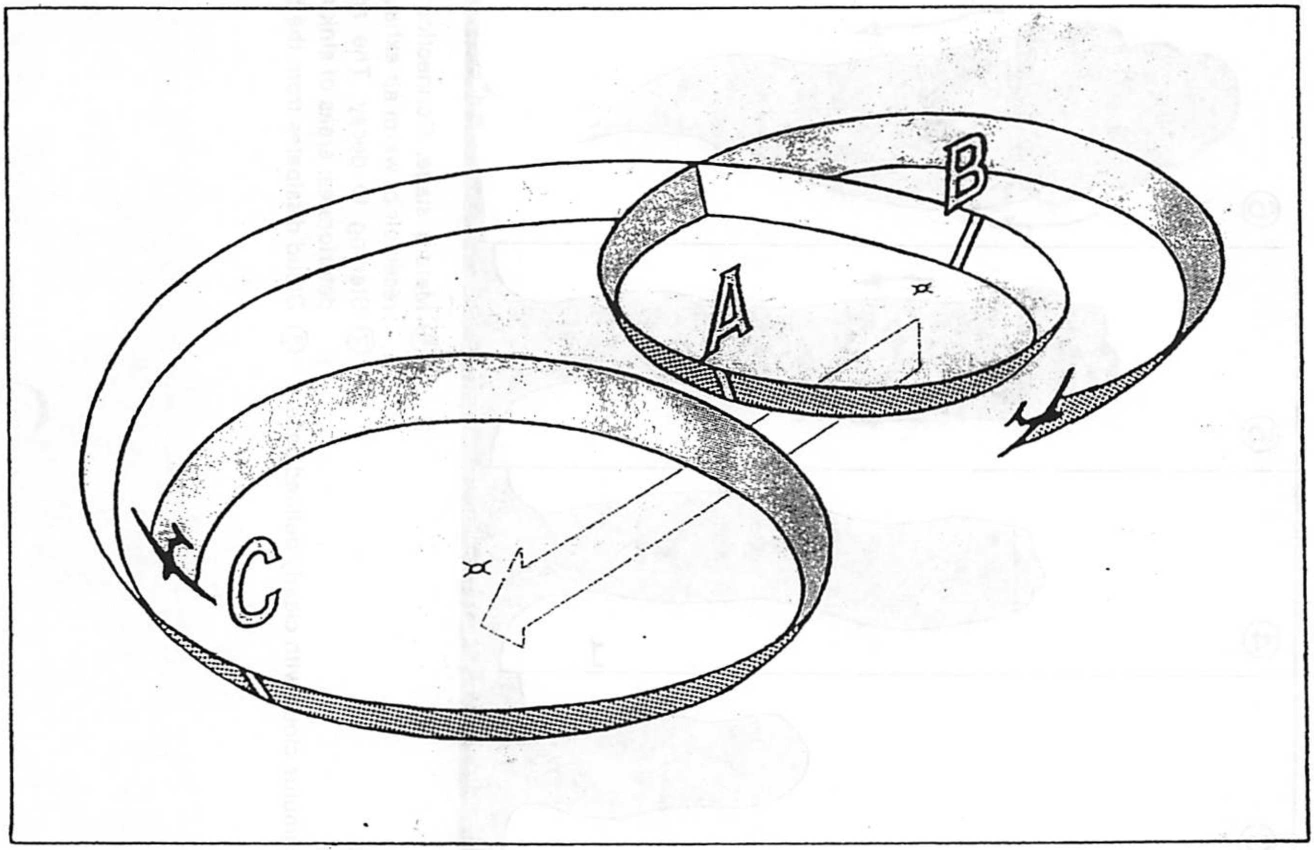
b From here on, the sink weakens and turns into lift. The pilot feels an upward acceleration and reduces his airspeed.

c Here is the core of the thermal. The upward acceleration ceases and the pilot starts circling.

Centering

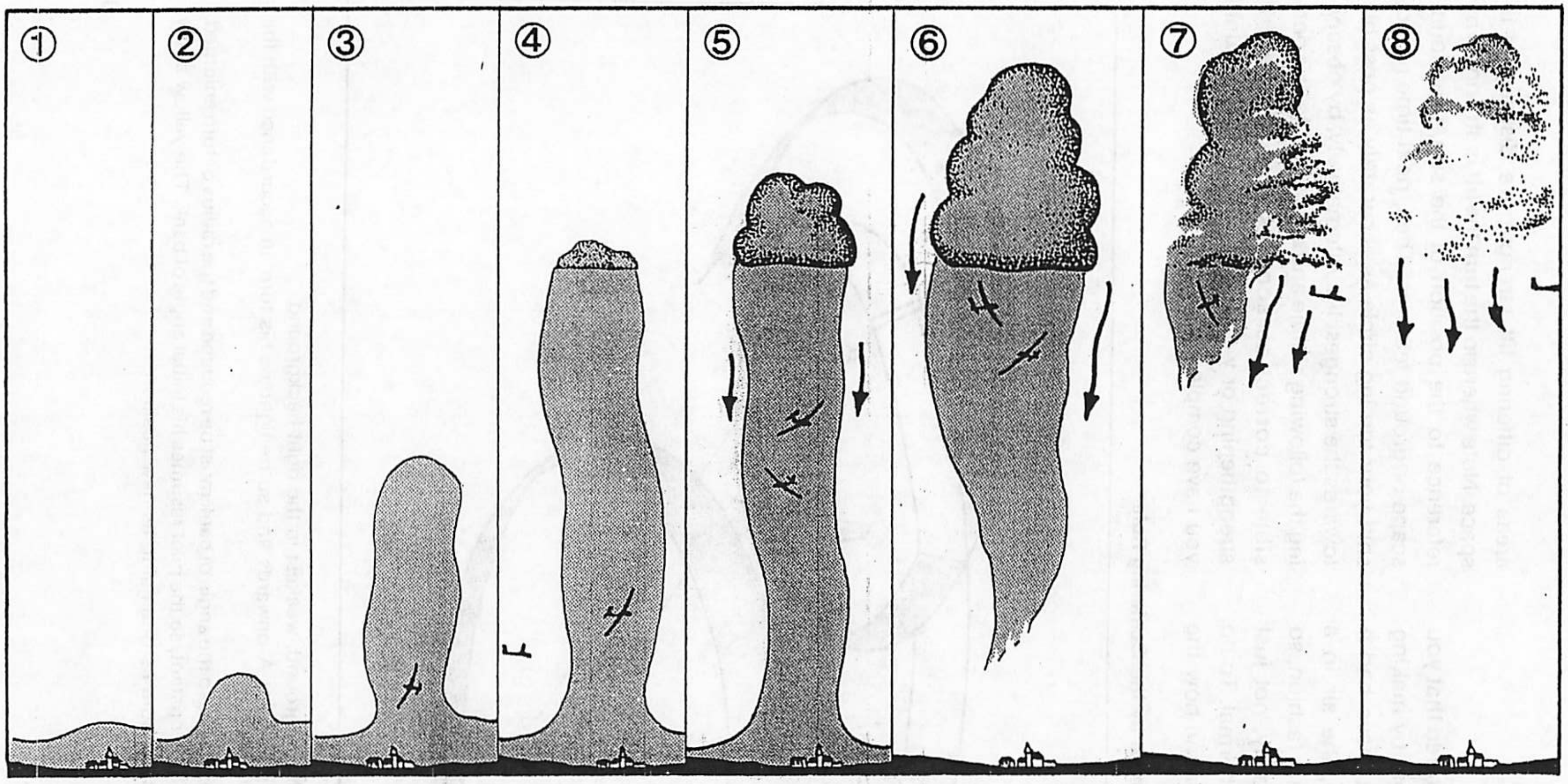
If your first circle in lift is so well centered that you cannot improve on your rate of climb by making corrections or shifting position, you have had a rare stroke of luck. What is more, the air in a thermal often rises in a highly irregular fashion, so it is necessary to re-center continually, not just once and for all upon entering the thermal. To do this it will help if you can try to imagine how the areas of differing lift strength are distributed in space. Note where in the turn the lift is strongest by reference to the position of the sun, the cloudscape or ground features. Then, next time round, shift your turning circle as accurately as possible towards the strongest lift. Alternatively, by observing the following simple and effective rule, it is possible to correct as soon as you feel the lift strengthening or weakening, without waiting until you have completed another turn.

Fig 51: Shifting Turning Circle in a Thermal by the Centering Rule



In the Figure, lift is strongest in the left foreground, weakest in the right background.
The pilot notes that the lift weakens from point A onwards and so he tightens his turn, in accordance with the centering rule.
From point B to point C, the lift improves again, so the angle of bank must be reduced and the radius of turn enlarged.
From point C onwards, the rate of climb is constant, so the pilot resumes his initial angle of bank. The yellow arrow indicates how the center of the turn shifts from its original to its new position.

Fig 49: Life-Cycle of a Thermal marked by Cumulus Cloud



① Source of warm air.
② Triggering.
③ Thermal column rises.
④ Cloud begins to form.
⑤ Rapidly developing cumulus cloud with clearly defined base. Good rates of climb.
⑥ Mature stage. Connection with the ground has been cut: reservoir of warm air exhausted.
⑦ Starting to decay. The area of lift shrinks; rate of climb deteriorates; areas of sink appear under the cloud.
⑧ Cloud dissipates from the base upwards. Sink.

Joining Other Gliders

This month's installment from Maurie Bradney's "Flying Faster and Further" highlights the act of joining other gliders in a thermal. Although the title is "Joining other Gliders", I realize the article only references thermal flying, as there is very little ridge soaring done in Australia.

This is the second in a series of three FF&F chapters to be reprinted in Westwind this year. The complete FF&F set is to be published by the Gliding Federation of Australia (GFA) sometime late in 1998.

Thanks again to Maurie Bradney and the GFA for sharing these articles. -Kempton Izuno

Submitted by Kempton Izuno

It is necessary to be able to thermal efficiently in company with other gliders. Sometimes there is only one thermal within range and the only alternative to joining them will be to land. On blue days all the better thermals will be marked by gliders, so that to avoid them would be to impose a severe handicap on yourself.

From a distance of 3 to 5 kilometres, aim directly at what you can eyeball to be the centre of the common circle that the gliders are making.

As you approach the others *Reduce Speed!* If you are carrying water ballast, this will take much more distance and time than when empty. The speed to adopt is 5 to 10 knots faster than your normal circling speed. This will give a crisp rate of roll and allow maximum manoeuvrability when you decide to turn.

In order not to frighten the people you are joining or yourself, you should aim at conformity with the gliders that are already established.

After reducing speed, sight the glider which will be near your level. Make small "S" turn manoeuvres so that after it passes in front of you, aim your glider at the tail of that glider as if you were going to shoot it down. Roll into the same angle of bank and follow the glider around the turn. This will put you into the ideal position between one third and one half a circle behind the other glider. You will both be able to see each other easily.

You should not be closer than 10 or 12 wingspans as the glider passes across your path.

Initially use only the other glider for positioning, do not take any notice of your own vario until you are following around in the turn. If the lift is not up to expectations you can then consider whether to leave or to make some centring adjustments.

This system will cope with joining up to three other gliders at the same level in a normal thermal core. If there are more you may have to join from below or find another core.

If you can talk to the gliders that you are approaching on the radio do so, if not, give a wave of the hand when you are near to indicate that you are watching them.

If you fly around the outside of the others and try to join by cutting in front you will frighten everyone and possibly get rammed by a glider that cannot manoeuvre fast enough to avoid you!!!

If you really must join them, after about a circle on the outside you will be below them and can join easily using the same system.

Once established in the thermal with other gliders you will find that to centre the thermal you will be able to use variations of bank. Straightening up and turning again usually makes too much conflict with the other gliders.

However, you will find that a good gaggle will be climbing at the maximum rate. Learn who will be in every glider, so you will know when you are in the best company.

You will sometimes find that you are climbing much better than the other gliders. Perhaps because you are empty and they have full ballast still. In these situations you will

CIRCLE TIME in SECONDS									
SPEED	Bank Angle in Degrees								
KTS	20	25	30	35	40	45	50	55	60
40	36	28	23	19	16	13	11	9	8
45	41	32	26	21	18	15	12	10	9
50	45	35	29	24	20	16	14	12	10
55	50	39	31	26	22	18	15	13	10
60	54	42	34	28	24	20	17	14	11
65	59	46	37	31	26	21	18	15	12
G force	1.06	1.10	1.15	1.22	1.31	1.41	1.56	1.74	2.00

CIRCLE DIAMETER in METRES									
SPEED	Bank Angle in Degrees								
KTS	20	25	30	35	40	45	50	55	60
40	237	185	150	123	103	86	72	60	50
45	300	234	189	156	130	109	92	76	63
50	371	289	234	193	161	135	113	94	78
55	448	350	283	233	194	163	137	114	94
60	534	416	336	277	231	194	163	136	112
65	626	489	395	326	272	228	191	160	132
G force	1.06	1.10	1.15	1.22	1.31	1.41	1.56	1.74	2.00

want to work around those gliders to climb above them.

On *No* account cut inside of any glider in front of you. You *Must* go around the outside or wait until that glider is just behind you and can *keep you in sight* as you change your circle.

Another problem is when you find that gliders may be making the same diameter turn, but are travelling at different speeds. As the pilot of the glider being overtaken cannot see the overtaking glider, responsibility for doing it safely must rest with the overtaking glider.

Most of the time gliders will be making circles less than 200 metres diameter. See the tables below. The size of the circles in the shaded area are too large to be in most thermal cores.

When within 100 to 200 feet, above or below other gliders, take extra care not to get into a position where you cannot see the other glider and they cannot see you. This "double blind" position has been responsible for several collisions in Australia, and has resulted in the deaths of at least three pilots. Remember you are not immortal!

Dear Editor:

Congratulations on the January WestWind. The Gantenbrink article on safety is worthy of wide dissemination. I agree that more of my friends die in glider accidents than in automobile accidents. I don't want to die in either, but at age 79 the dangers increase due to reaction time, deteriorating eyesight, hearing, memory, etc. To counteract these, I get yearly assessments of my flying skills, and maintain currency and proficiency. Now I favor flying dual, asking the other pilot to help with traffic, and to inform me when he is not happy with my flying. I also like to land at an empty airport. At Truckee for instance, I will circle the airport high to observe the traffic, the 4 windsocks, imminent glider operations, and monitor the AWOS. If I am lucky, I will land on an empty airport, announcing my intentions on Unicom. Soar Truckee is very diligent in towing me off the runway in case I can't roll onto a taxiway. While thermaling, if I am joined by another glider who won't or can't keep a 180 degree position, I leave and find another thermal. I always prefer a ship with a transponder. I stack the deck in my favor. I tried competition for one year and was appalled at the safety level. Cross-country is an airport hopping exercise now with the higher performance two-seaters. I appeal to our experienced pilots to comment on safety.

—Emil Kissel

The Impact of Rate of Climb

Negative Training

Why Local Flying Doesn't Help as Much as it Should...

The flight training syllabus specified by the FAA isn't really aimed at producing cross-country pilots. It is designed only to lead up to the Private or Commercial certificate—the rest is up to you.

That's bad enough as it is, but even worse is the fact that your earlier training can actually hinder your cross-country aspirations. One of the buzz words in flight training circles is **negative training**, defined as "experience that inadvertently reinforces inappropriate habits or responses." In the context of cross-country flying, several aspects of the glider flight training you've already received probably fit this description. While every pilot is an individual, the typical student or newly-licensed glider pilot will tend to

•stay very close to the airport

•treat all thermals as discrete, isolated lift sources

•center all thermals, spiraling but never dolphining

•fail to "shift gears" when changing situations demand new strategy

•have difficulty accepting long interthermal glides

And here's the Big One: in the typical club or rental environment, your goal after takeoff was "to get your hour in." This type of task places a premium on finding and **remaining** in lift, no matter how weak. Most pilots in this stage will develop a tendency to remain in lift long after they've stopped climbing, effectively reducing their average rates of climb. This is exactly what a cross-country pilot should **not** do--in other words it's more **negative training!**

On the next page we'll see just how important it is for a cross-country pilot to maintain a high average rate of climb whenever he stops to use a thermal.

The Impact of Rate of Climb, continued

A "round numbers" demonstration

Let's consider a 300-km Gold Distance or Diamond Goal flight. 300 km is 162 nm, and a reasonable ground speed for the cruise portion of the flight (that is, the glides and not the climbs) is 60 kt. (This corresponds to a 50-kt IAS at an average altitude near 10,000 ft.) 60 kt equals 1 nautical mile per minute, so a flight of 162 nm will involve 162 minutes of gliding; 162 minutes is 2:42. So much for the cruise--what about the climb?

At a glide ratio of 30:1, that 300 km will require a total climb of 300 km/30=10 km. Ten kilometers is ten 1000-meter Silver Altitude climbs, or 32,810 ft. We'll round that to 33,000 ft and then deduct the first 3,000 ft for the tow. How long will it take us to gain 30,000 ft?

At an average climb rate of 1,000 ft/min, it will take us thirty minutes, making the total flight duration (climb plus glide) 3:12. Even after throwing in an extra thirty minutes for "getting out of town," this is still a manageable 3:42. This means that we'll have plenty of daylight for the entire trip, with room for errors.

At a more realistic climb rate of 600 ft/min, our total climb time is still a reasonable fifty minutes--just twenty minutes longer. But an average climb rate of 300 ft/min will require us to spend 1:40 climbing! To summarize:

300-km Timetable

climb rate	time to climb	time to glide	30-min pad	total time
1000 ft/min	:30	2:42	:30	3:42
600 ft/min	:50	2:42	:30	4:02
300 ft/min	1:40	2:42	:30	4:52
200 ft/min	2:30	2:42	:30	5:42
100 ft/min	5:00	2:42	:30	8:12

You can see that no other factor could have as great an impact as climb rate. Even if you could somehow manage to cruise at 100 kt you would only shave about an hour off these flight times!

The Impact of Rate of Climb, continued

Is This Trip Really Necessary?

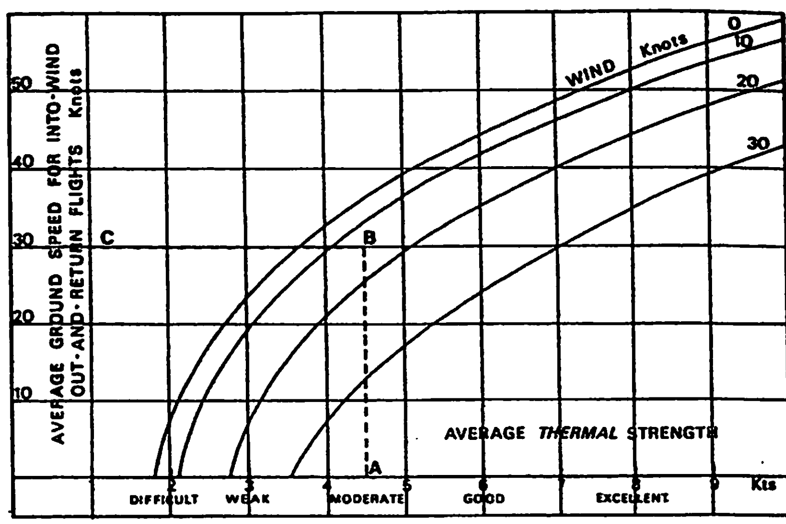


Fig A9.1 Course Length Calculator

TO USE:

1 Determine thermal strength, say 450 fpm (4.5 knots). Enter at A.

2 Determine wind speed, say 15 knots. Go vertically up from A to hit 15 knot wind line (point B)

3 Read average ground speed over closed circuit by going left from B to C

4 Multiply speed by desired flight time in hours (say 3) to obtain length of circuit. Therefore 30 x 3 = 90 nautical miles (167 km)

NOTES

This chart assumes uniform thermal distribution without streets on an out-and-return along the wind for a Libelle. Streets will increase the average speed

Use this chart to

- Flight plan realistically
- Assess your own progress
- Develop a sense of when to "shift gears"
- Decide when and whether to abort a task

Technical Thermalling- Chad Moore

The standard sailplane polar can be redrawn for non-level flight. Sinkrates increase sharply with increased load factors. At a 60° bank, the load factor is 2, and sinkrate is increased 2.83x.

Sinkrate=loadfactor $^{1.5}$

Speeds are also increased. At a 60° bank, the stall speed is increased 1.41x.

Stall Speed=loadfactor $^{0.5}$

30 *The Paths of Soaring Flight*

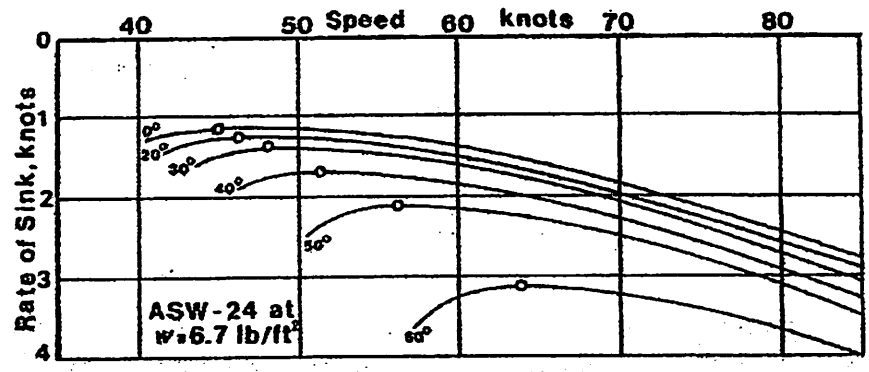
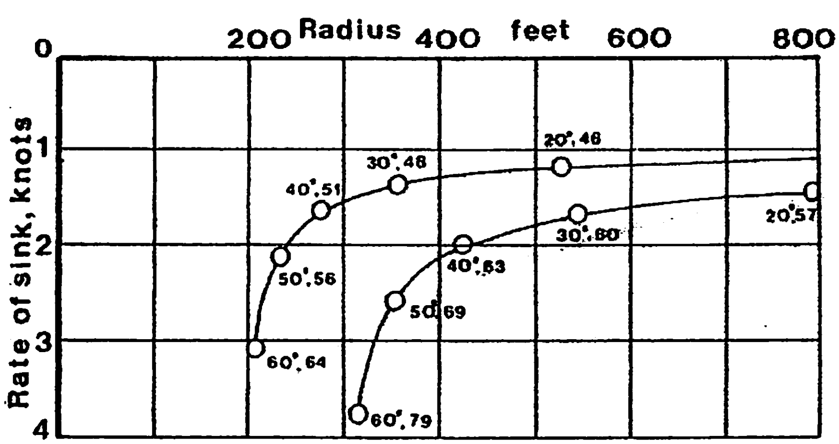


Fig. 4.4. The effect of angle of bank on the performance of the sailplane of Fig. 3.1.

Less severe banks, such as 45°, have reasonable sink and stall values.

The Equations of Motion 31

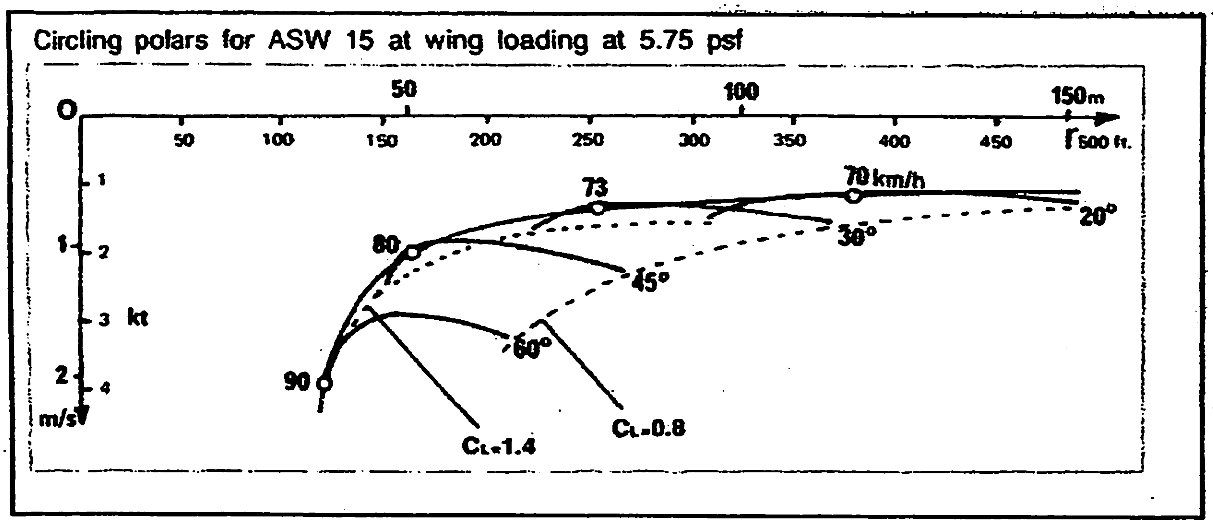


Turning radius, sinkrate, and minimum sink speed are plotted here. Two wing loadings are shown, represented an unballasted and ballasted standard class glider.

In both cases, there is a turn in the polar at 45°. The ballasted glider has a distince disadvantage in a thermal. To achieve the same radius, a 50° bank is required to keep up with a 30° bank in an unballasted glider. Sinkraes are also significantly higher.

Great Basin thermals often have a narrow core, and the strong lift may only be found within a 250' radius. Turning radii greater than 400' (sea level equivalent) are seldom effective for single core thermals. The exception to this is near the top of a thermal, at cloud base where latent heat release augments thermals (cloud suck), in multicore thermals, or when working shear lines and the like.

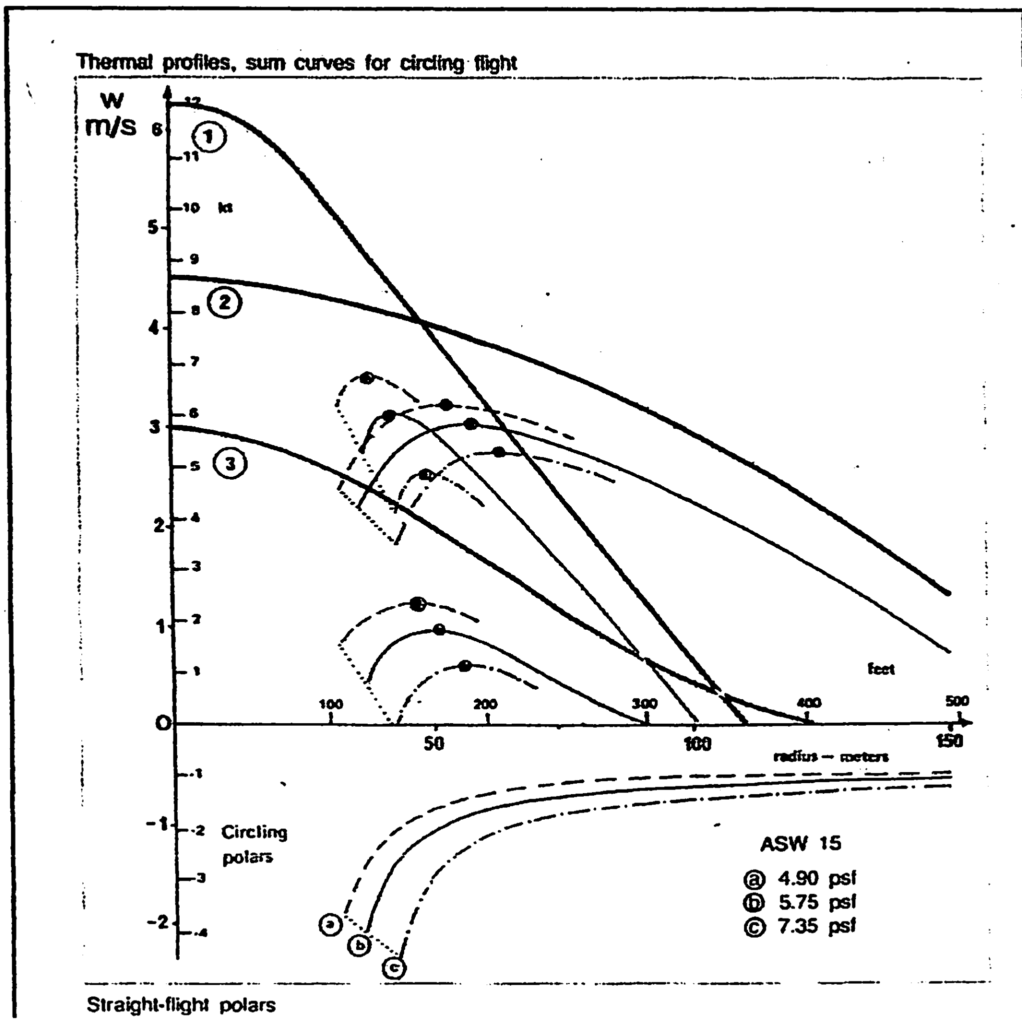
The optimal bank, ballast condition, and speed depend on both the strength of the thermal, the width, and the rate that lift increases toward the core. In the absence of more information, a bank angle of 45° is often close to the optimal configuration.



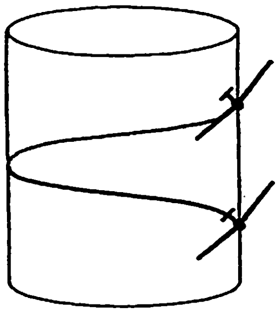
Reichmann makes an astute observation in his book "Cross-Country Soaring. Minimum sink speed may not be the optimal speed to fly for a given bank angle. Since reducing turn radius often has a more beneficial effect than reducing sink rate, Reichmann's theory suggests that at steeper bank angles, flying slightly slower than minimum sink speed is more beneficial than steepening bank angle. In the "circling polar" above, four polars are plotted for 20°, 30°, 45°, and 60° banks. At 20° and 30°, the optimum speed to fly is at the top of the polar (e.g. the minimum sink speed). But at 45° the optimal speed to fly (shown by an open circle), slides off to the left. This effect is even more pronounced at 60°.

However, the optimal speed to fly at 60° is just a fraction above stall speed in non-flapped sailplanes. This is impractacle, and potentially dangerous at 60°. Tight core thermals that require such a small turning radius are bound to be turbulent, thereby dictating more of a speed margin. Certain sailplanes may also lack the elevator authority and flight stability at these bank angles and speeds, but the theory is still interesting.

The lower figure shows three wing loadings on three thermal models. By "warping" the polar relative to the thermal strength, the effect of wing loading can be graphically demonstrated.

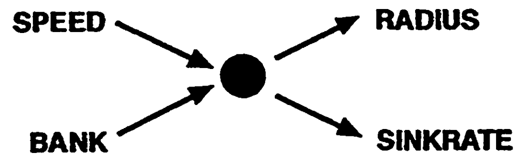


Thermalling "Helix"



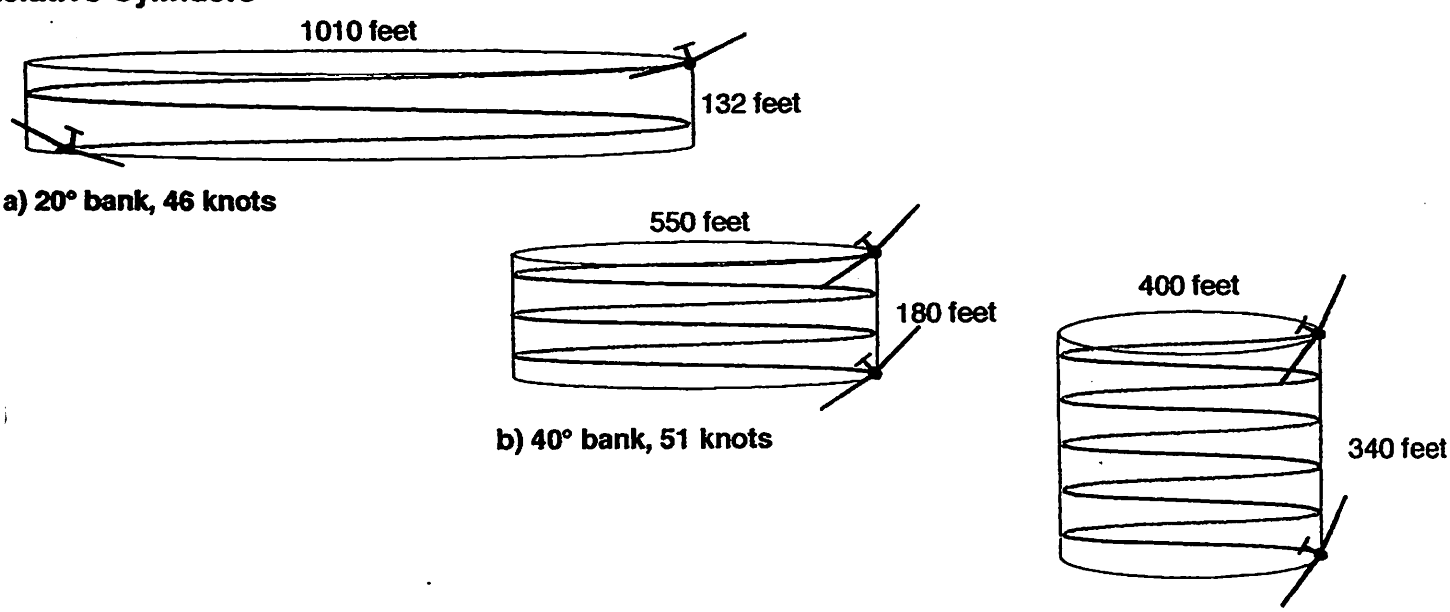
Circling in a thermal is actually a helix with reference to the airmass.

Pilot Inputs



The pilot chooses the appropriate speed and bank, which results in a certain radius and sinkrate to best utilize the thermal.

Relative Cylinders



a) 20° bank, 46 knots

b) 40° bank, 51 knots

c) 60° bank, 63 knots

Three cylinders encapsulating 1 minute of flight for various bank angles. Data is for a 40:1 modern standard class sailplane. Drawn to scale.

Circling Forces for level flight

Bank Angle (Theta)	0°	5°	10°	15°	20°	25°	30°	35°	40°	45°	50°	55°	60°	65°
Load Factor	1.00	1.01	1.02	1.04	1.06	1.10	1.15	1.22	1.31	1.41	1.56	1.74	2.00	2.37
Horizontal Speed Factor	1.00	1.00	1.01	1.02	1.03	1.05	1.07	1.10	1.14	1.19	1.25	1.32	1.41	1.54
Vertical Speed Factor	1.00	1.01	1.02	1.05	1.09	1.16	1.24	1.35	1.49	1.68	1.94	2.30	2.83	3.64
Circling Radius @ minimum sink	-	2000	1000	680	505	415	350	305	275	250	230	215	200	195_{ft}

Load factor is 1/cos θ. Forward velocity is load factor raised to the 0.5 power, while vertical velocity is the load factor raised to the 1.5 power. Circling radius (in feet) is based on a modern standard class sailplane with a minimum sink speed in level flight of 45 knots flying minimum sink speed for that particular bank angle. Data is for sea level atmospheric pressure.

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.

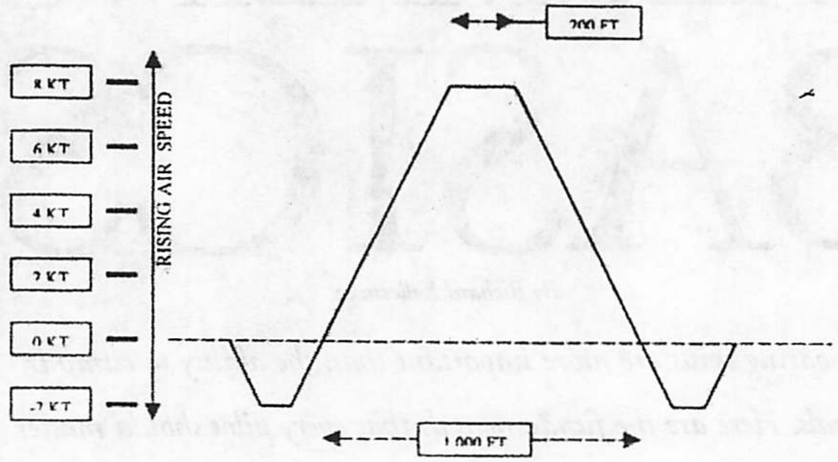
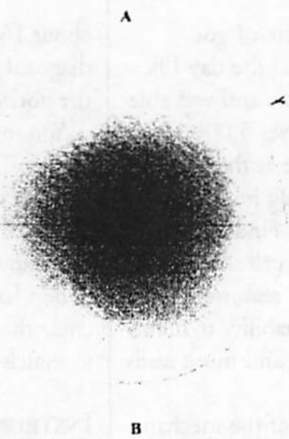


Figure 1: Thermal Model. 1a depicts the speed of the rising air across the thermal. There is an annular region of sink. The area of lift is 1,000 ft. in diameter, with a core of 200 ft. The lift increases linearly from -2 kt to +8kt. Note the vertical axis is speed, not height.



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

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

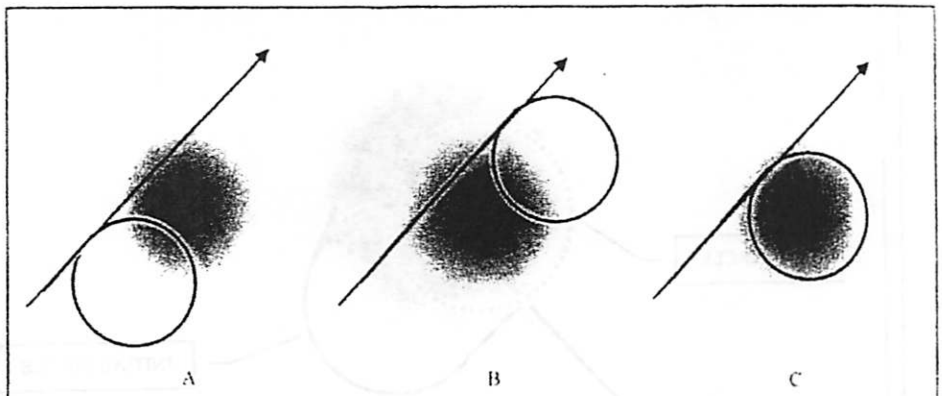


Figure 2: Timing the Turn. Getting the timing right always helps, even if things don't go quite as well as they have for Pilot C. A) Too soon. Even with the correct turn direction, Pilot A gets to fly in sink. B) Too late. Pilot B also flies in sink, but at least he knows where he has come from. C) Just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

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

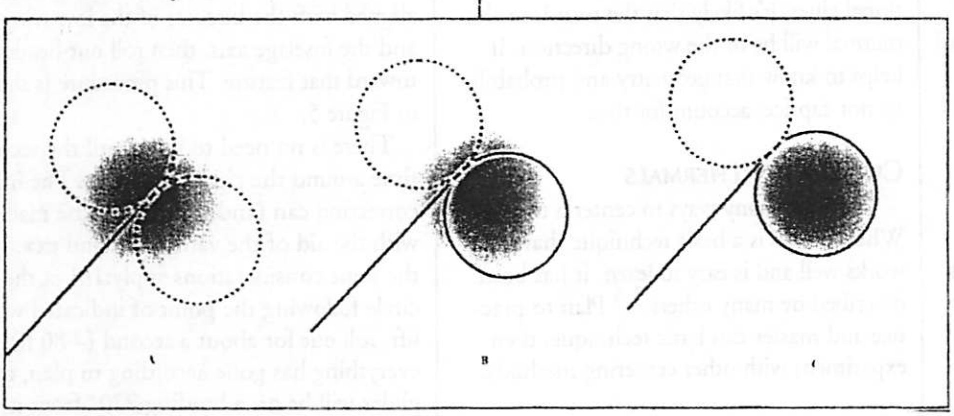


Figure 3: Which Way To Turn. The further the entry courseline is from a diameter, the greater the cost of a turn the wrong way. A) No need to worry — both ways are wrong, and there is no way to distinguish. B) Right turn is favored, but unless the right wing lifts prior to the turn, the pilot does not know this. C) The sufficiently lucky or skillful pilot can perfectly time 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.

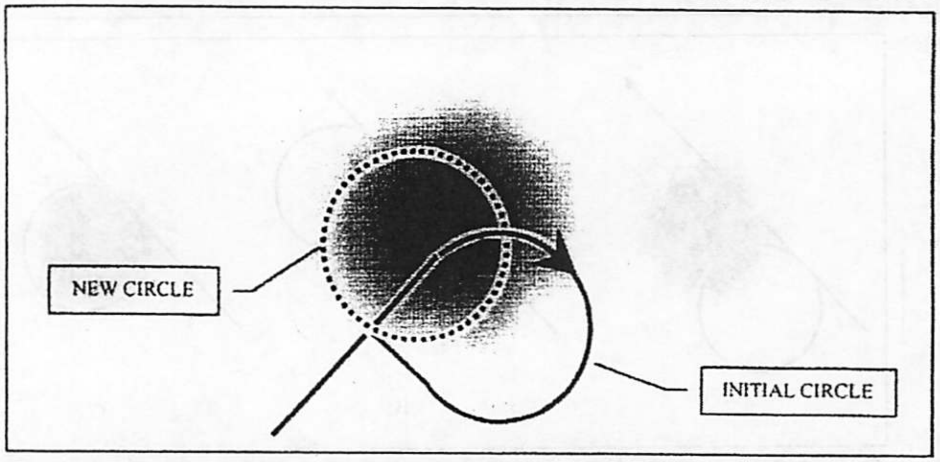


Figure 4: The Initial correction. With the vario heading down for more than half the initial circle it's time for the correction: As the glider comes around to a heading 90° to the entry heading, roll out, then roll back in again, moving the circle in the direction of the lift. This only works if the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

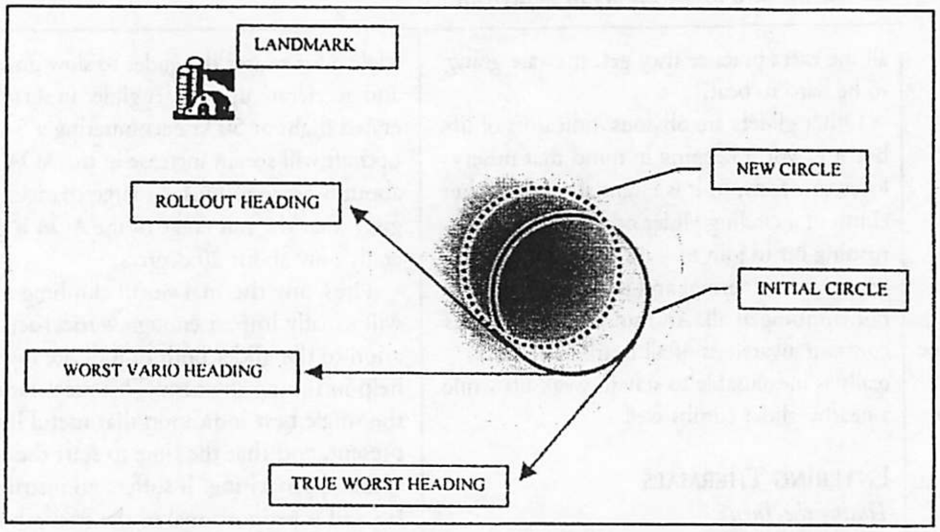


Figure 5: Centering. In a 45° bank, a 2 second vario lag is 1/8 of a circle, or 45°. This is easy to judge. 45° after the worst vario reading is the time to rollout. This, too, is easy to judge since the bisector of the wing and the fuselage axis is 45° from the worst vario heading. At the worst vario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

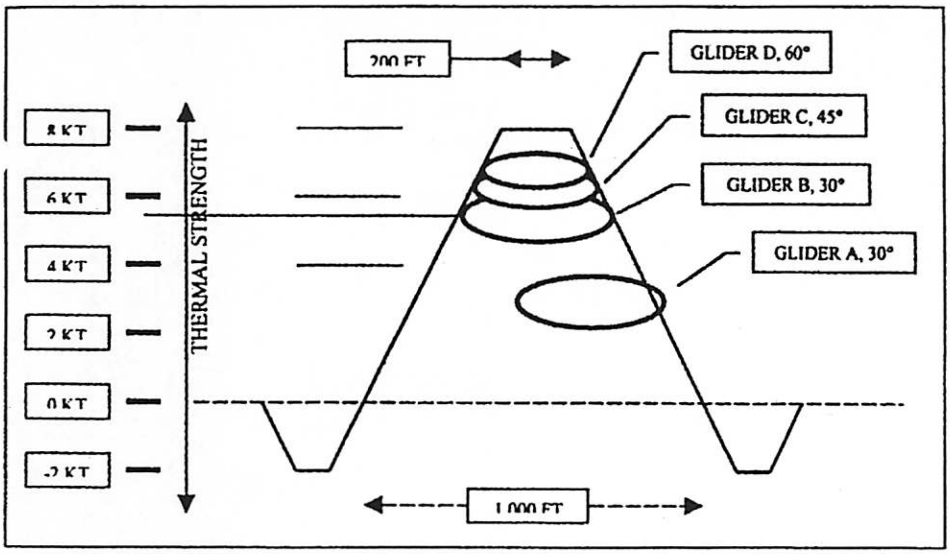


Figure 6: Optimizing The Climb. Glider A is neither centered nor optimized. Glider B, with the same size circle is centered and climbing better. Glider C has a smaller, centered circle and is able to use better air. Glider D is in even better air, but the bank is so steep that sink rate is now an issue.

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.