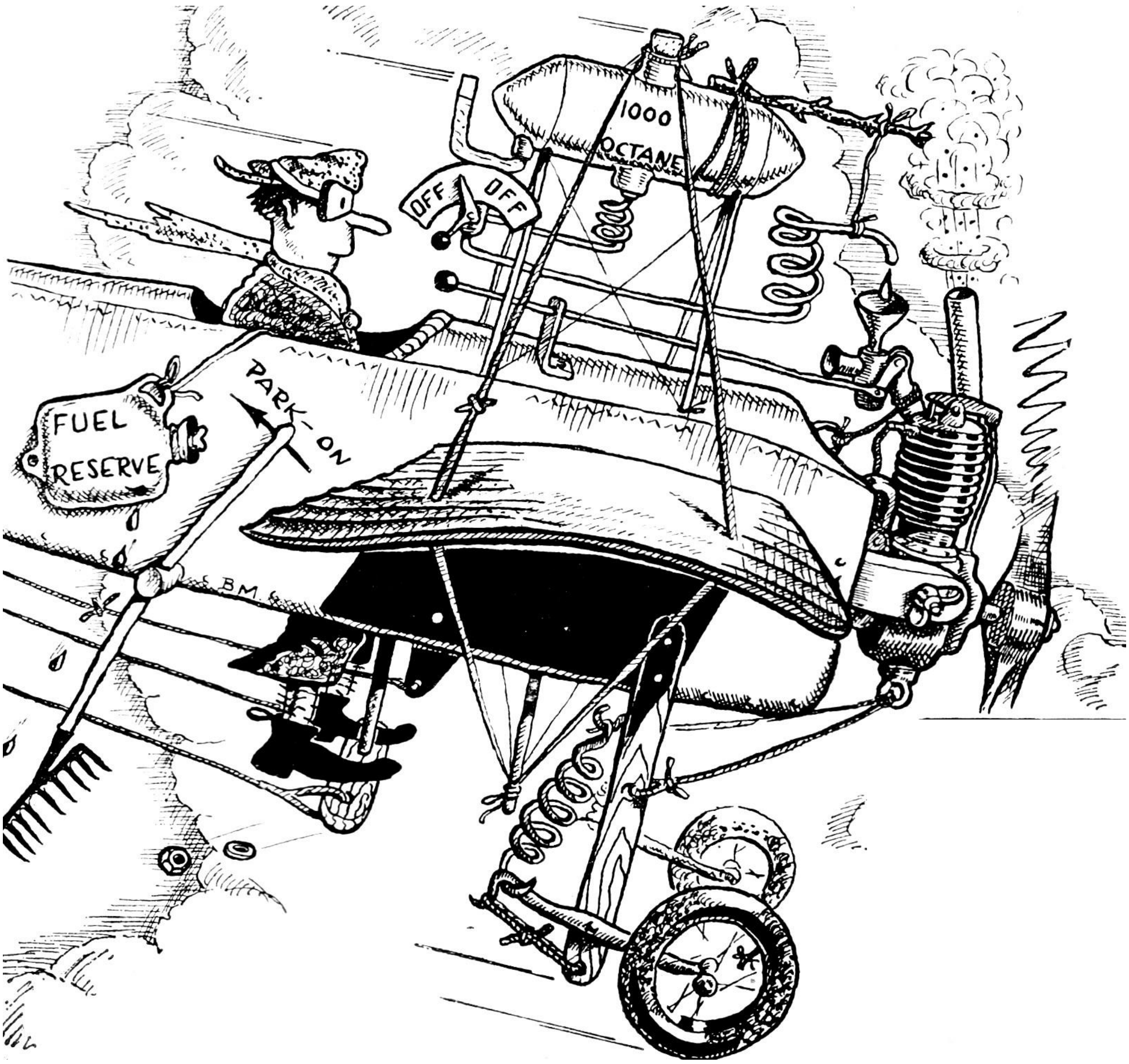
FLY BETTER

(The things you should have been taught when learning to fly.)

Book Two – Fourth Edition

Aeroplane Handling Techniques



Transcripts of lectures about flying by

Noel Kruse

Founder of the Sydney Aerobatic School

I dedicate this book to my very good friend and fellow aviator, Wing Commander Phillip Astley AFC.

Phil died on 21 October 2009.

Phil and I learned to fly together in 1961, at the Royal Victorian Aero Club, doing our 'first solos' within a few days of each other. We became good mates and remained so until his death.

We followed each other around the Royal Australian Air Force for over twenty years and upon leaving the RAAF, I started the Sydney Aerobatic School and Phil joined the Australian Civil Aviation Safety Authority, where he focused on flight training standards. In 2009, despite his illness, Phil was great assistance to me in the editing and critiquing of the first book in this series.

Aviation in Australia is diminished by his passing.

Noel Kruse

BOOK TWO CONTENTS

Edition Four

Fourth Edition 2024

Introduction

This is the fourth edition of Book Two. This book defines specific flight control techniques which are based upon the aerodynamic principles explained in Book One. In the last chapter of this book I have repeated, for your easy reference, many of the key statements and 'rules of thumb' contained in Book One.

It is often difficult to divide the explanation of a principle from the actions required to observe it, which is why some of the lessons of Book One also contain details of the flight control techniques associated with the principles expounded. Specifically, side slip, stall, and spin recovery techniques have been fully covered in Book One and will not be repeated in this book. In other cases, control techniques mentioned in Book One will be expanded further herein, such as angle of attack control and turning, whilst other techniques will be introduced which have not been alluded to in Book One and which, I am sure, will be quite new to most readers.

Some experienced aviators may read this book and say "of course, I knew that", or "that's the way I do it." And that may be so, but I say to them, search your memory; were you taught these things or did you discover them for yourselves, and how many hundreds or even thousands of flying hours did it take? I was not taught all of these things. I discovered many of them for myself after years of flying. When I decided to take on the task of teaching others to fly better, I spent a considerable amount of time converting what I had learned over the years into specific methods of instruction in order to eliminate the long period of trial and error that many experienced aviators go through.

I recall, many years ago when I was the CFI of the Sydney Aerobatic School, during one of my many instructor renewal tests, my tester asked me to show him one of my 'radical' techniques, so I told him I would show him how I teach engine out forced landings. I think he expected inverted spinning or something as dynamic, because his initial reaction was "ho hum". During the briefing his interest was rekindled, and after my flight demonstration he confessed to me that he never used the 'standard' method taught either, that he had always just 'eyeballed it'. He asked if he could fly the procedure his way to the same field for comparison. Throughout his approach to the field he kept remarking that my reference points exactly coincided with his eyeball assessment. He finally declared that I had formalized a technique that had taken him thousands of hours to develop for himself, and made it accessible to student pilots from lesson one!

My tester was a very experienced aviator, a former fighter pilot who had flown P-51 Mustangs in Korea, and was now the most senior flight operation inspector in the Australian Civil Aviation Authority. I passed the test.

Of course there were also many ‘high time’ pilots who never ‘got it’ for themselves, and they regarded my techniques as bordering on heresy! (I was told this often.) Many of these pilots are still out there flying around, as are their progeny. You are sure to meet them and be confronted with the same myopic view of how to fly. Hopefully you will, after reading and understanding this book, be able to transcend their limited view of flying and have a wonderful life in the sky, as I have had.

Lesson One

Attitude Reference Point

“Attitude plus Power equals Performance”. Set the correct attitude, set the corresponding power and you will achieve the performance from your aeroplane that you expect. This is a phrase used often by flying instructors like some magical incantation, which it’s not. However, within certain limits (like density altitude and/or climb attitude), it is a useful teaching aid. But in a modern aeroplane, sometimes setting up this combination of power and attitude is easier said than done.

What is meant by ‘performance’ in this context? It means flight path and speed. Flying level, climbing, descending and turning, fast or slow; all of these things are (as I said, within certain limits) accomplished by setting the correct attitude and the corresponding power. Now setting the power is not too difficult. Move a lever or levers in the cockpit, set some numbers on a dial, and presto, you have the power setting you want. But setting the attitude is not so straight forward.

What do we mean by ‘Attitude.’? Attitude, in this context, is the relationship of the internal reference points of the aeroplane to the outside world. If we were talking about driving a car, we would say that we point the front of the car (internal reference point) down the road (outside world). So in an aeroplane we point the front of the aeroplane at…..what?

The part of the outside world which is most helpful to an aviator is the horizon. The horizon provides the pilot with the reference which enables him or her to set both pitch and bank attitudes, or a combination of both. In mountainous terrain or on hazy days it is difficult to see the true horizon, and therefore difficult to set precise attitudes, so early flying training is best done away from these two things. Later the pilot can learn how to compensate for these limits on determining attitude, but during early training having a clear straight horizon is a good idea.

Which bit of the aeroplane do we point at the horizon?

This is where the difficulty arises. A modern light aeroplane is designed to give the pilot reasonably good forward visibility. The horizontally opposed ‘flat’ engines used on most modern light aeroplanes allow a good clear view over the ‘nose’ of the aeroplane, which means that in straight and level flight the nose appears well below the horizon. The pilot’s eye line to the nose is depressed about 10º from the aeroplane’s flight path in these aeroplanes, (Figure One).

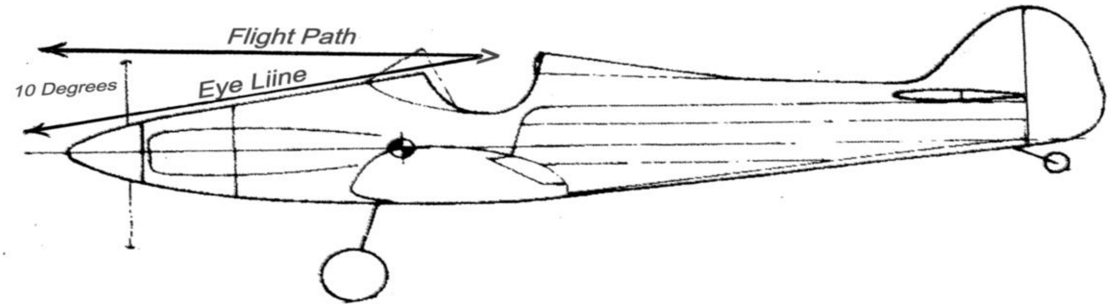
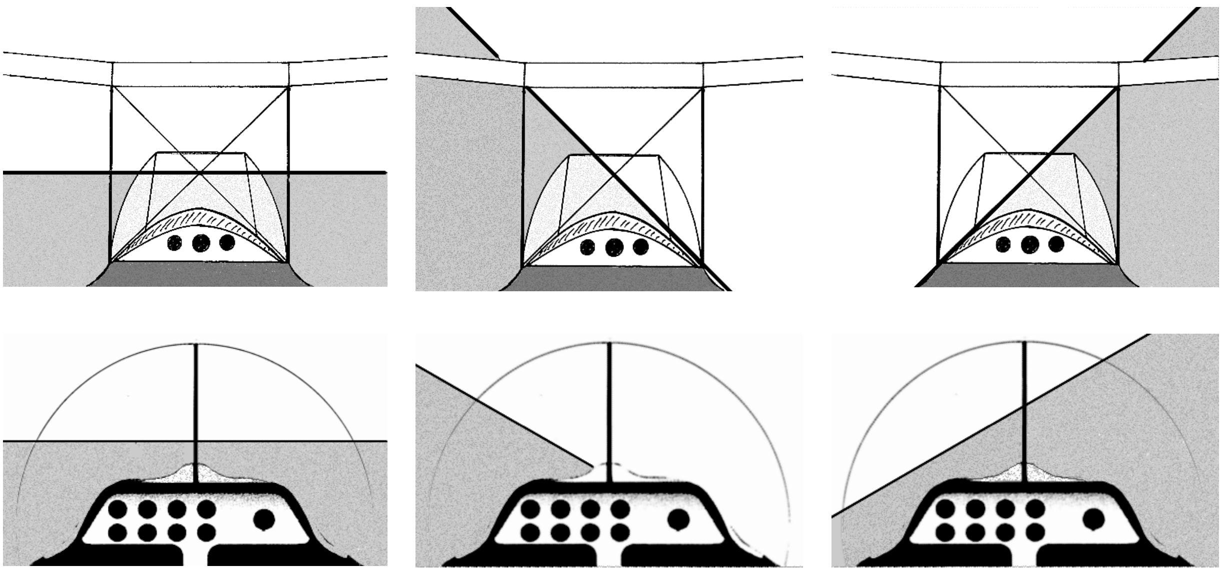


Figure One - Side view of eye line over nose.

Most modern training aeroplanes also have a side by side seating arrangement, which means that the student pilot and the instructor are sitting off centre. This off-centre seating can have a detrimental effect upon determining attitudes in a turn, and the difference in perspective between student and instructor can also add difficulty to an instructional scenario.

Back in the 'good ol' days', most training aircraft had tandem seating, where the student and the instructor sat one behind the other. In the Tiger Moth, the pilot's seat (hence the student's seat) was behind the instructor, and both pilots were sitting on the centre line of the aeroplane. They were also sitting behind a much longer nose; indeed in the Tiger Moth the student had the majority of the aeroplane out in front of him. From the rear seat of the Tiger Moth both wings and their associated struts and cross bracing were always within the pilot's field of view, so pointing the 'front' of the aeroplane at the horizon was not too difficult. The cross bracing of the centre section 'cabane' struts provided a set of 'cross hairs' to sight through, and the angle of these same bracing wires gave a good bank angle reference when turning too. Compare the pilots view out of the front of a Tiger Moth to that out of the front of a modern training aeroplane, (Figure Two).



Straight & Level **Left Turn** **Right Turn**

Figure Two – Tiger Moth & modern aeroplane in level flight attitudes.

Notice that the attitude of the modern aeroplane is not as clearly defined as it is in the older aeroplane; and the attitudes in left and right turns in a modern aeroplane, because of the side by side seating, are significantly different and even more difficult to determine with any precision, (and where do you put the horizon when reversing from a turn one way into a turn the other way?).

Why is setting precise attitudes so important? A one degree deviation from the correct level attitude when flying at 120kts will cause a rate of climb or descent of about 200ft per minute. A student pilot is expected to be able to fly much more accurately than this, but with an attitude reference about as precise as judging the water level in a goldfish bowl it is difficult. (In an SR71 flying at Mach 3, a one degree attitude change produces a 3000ft per minute deviation from level flight!)

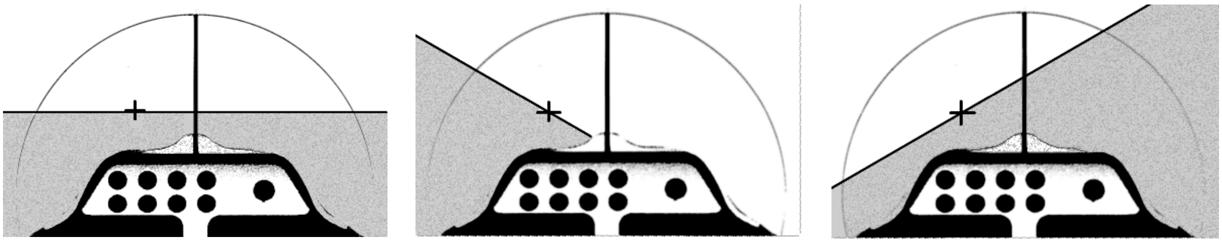
Because of this problem of determining the attitude from the 'goldfish bowl' out of the front of the aeroplane, most private pilots have gotten into the bad habit of continually 'chasing' the aeroplane's altimeter and airspeed indicator, or flying by reference to the aeroplane's 'attitude indicator' (if it has one). So here they are on a beautiful sunny day with a clear horizon and a spectacular view outside, spending half the time looking inside the cockpit at the instruments. What a waste of a beautiful day, and what a hazard to the other aeroplanes flying in the vicinity. (Whose pilots may also be spending too much time with their head 'inside' the cockpit!)

The SR71 pilot and all modern jet fighter pilots have a small 'dot' projected onto their HUD (Head Up Display) called a 'Velocity Vector', which continually indicates exactly where the aeroplane is going. So all they have to do is hold the velocity vector on the horizon and the aeroplane is flying level. (Just like the Tiger Moth pilot!) Wouldn't it be great if a modern light aeroplane could have such a device?

A velocity vector projected onto a HUD involves about a million dollars worth of electronic equipment, so we are not likely to see one fitted to a light aeroplane anytime soon. But what if we could set up something which was perhaps not as precise, but much much cheaper? Say $1? Well, that's possible; I call it an ARP which stands for 'Attitude Reference Point'. It involves the use of a $1 white board marker pen, and thirty seconds of accurate flying. How does it work?

First you must purchase a white board marker pen, preferably a dark colour (black is good), and take it with you on your next flight. Once airborne and flying level at cruising speed, point the aeroplane at a clear horizon and set it up dead straight and level (using the instruments if you have to). Hold this attitude whilst you draw a horizontal line about one inch long (2.5cm) on the windscreen precisely on the horizon and directly in front of you. Then draw a vertical line the same length, through this horizontal line and directly in front of you, to form a cross on the windscreen. The point where these two lines intersect is your Attitude Reference Point (ARP).

The ARP can be used to set attitudes much more precisely than can be set using the 'goldfish bowl' method. The following diagrams show the ARP in three standard level attitudes; notice how the offset seating is no longer a factor in determining turning attitudes, and when reversing from one turn to the other, the ARP is simply held on the horizon. (Figure Three).



Straight & Level **Left Turn** **Right Turn**

Figure Three - Level flight using the ARP.

Now I must emphasize that this is not a velocity vector, it is only a cross on a windscreen and therefore it has some errors. The first is that it relies on the pilot's head not moving around too much. So if you are in the habit of 'cocking' your head to one side when in a turn, it will give you an incorrect attitude reference. (If you are doing a balanced turn, there is no reason to align your head with the outside world as your gravity is straight up and down relative to you.) Assuming that your head doesn't move too much during a turn, you may still detect some minor errors, particularly as the 'G' builds up in a tight turn. There are two reasons for this, the first is that the angle of attack increase necessary to make the turn also increases the difference between where the aeroplane is going and where it is pointing, and the second is that you will suffer what I call 'Eyeball Sag', as a result of the 'G force' compressing your body slightly and pushing you down into the seat cushion a little. So to fly a level 60º banked 2G turn, you will need to position the ARP a little above the horizon to compensate for these two effects, as shown in Figure Four.

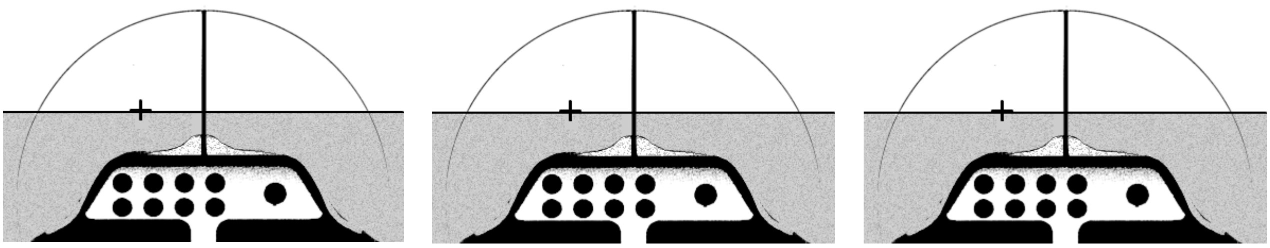
Left Turn **Right Turn**

Figure Four - ARP position in a 2G turn.

Even though some ARP adjustments may be necessary, they will be easily judged in terms of the size of the cross, they won't be gross and they will certainly be far more accurate than the 'goldfish bowl'. The ARP can, with the stroke of a pen (literally), increase the accuracy of your flying significantly, and allow you to spend a lot more time looking out the window. Indeed you have to look out the window for it to be of any use to you. (I will return to the flying technique in a 2G turn in Lesson Eight)

Now that we have set up the ARP at cruising speed, what happens to it if we slow down? Slowing down whilst maintaining level flight involves changing angle of attack and therefore changing attitude. This means that the ARP will no longer be coincident with the aircraft's flight path, and its usefulness will be reduced. However, if - having slowed the aircraft - we then lower some flap, we will have to reduce the angle of attack and attitude to maintain level flight. By selecting the right combination of flap and speed we will be able to put the ARP back onto the horizon, thereby restoring its usefulness. How much flap should be used? This will depend upon how much you want to slow and what the standard flap settings of your aircraft are. You will need to experiment with this to determine the speed that corresponds to each flap setting, which produces level flight with the ARP on the horizon.

The aeroplane I used for basic flying training was the Robin 2160, and for that aeroplane, which has a level flight cruise speed of 120kts, I established two 'standard' level low speed configurations. 85kts with 15º flap, and 70kts with 35º flap. On the later models of this aeroplane the initial flap setting was reduced to 10º so the corresponding speed had to be 'bumped' up to 90kts to keep the ARP on the horizon. Figure Five shows these three configurations. Note that in each case the ARP is on the horizon and the aeroplane is flying level.



120kts, 0º Flap, 2500rpm **85kts, 15º Flap, 2100rpm** **70kts, 35º Flap, 2100rpm**

Figure Five – Level attitudes at different speeds and flap settings.

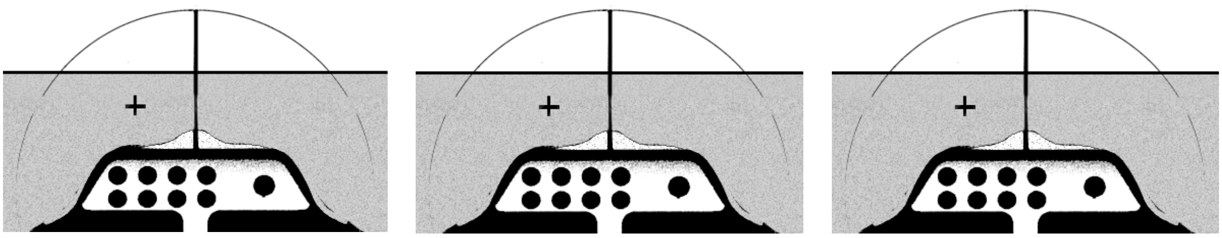
It is also interesting to note that only two power settings were required, 2500rpm at 120kt, and 2100rpm for both slow speeds. The extra drag of full flap slowed the aeroplane from 85kt to 70kts without the need for a further power reduction. Depending upon the design of your aeroplane you may also find that there is no significant pitch trim change between these three configurations either. (Book One - Lesson Six, page 150.)

Whilst the aeroplane that you fly may be different; a couple of useful slow speed configurations can easily be determined by setting the flap and adjusting the airspeed (whilst maintaining level flight) until the ARP is back on the horizon. (Obviously you will only extend the flap after you have slowed to an airspeed below the flap limiting speed.)

Of what use are these slow speed configurations? Flight at low level in reduced visibility is often safer when we are not blasting along at cruising speed, so being able to slow down but retain the good ‘view’ over the nose by using a normal attitude can be very handy. But the most common use is when we are stuck behind a slower aircraft in the traffic pattern, and have to keep it in sight.

Can these three ‘set ups’ be used for other than level flight? Yes they can. You may recall from the discussion on descending at the end of Book One - Lesson Nine, that I said that a cruise speed descent can be made by setting an appropriate attitude and adjusting the power to maintain cruising speed. Well the attitude required to do this does not have to be extreme, and will involve setting about a 4º nose low attitude, which will correspond to about two ‘cross widths’ below the horizon, and that is easily judged. This attitude will produce a ‘comfortable’ rate of descent, and, since the airspeed hasn’t changed, the ARP will still indicate where the aeroplane is going. So whatever the ARP is pointing at on the ground is where the flight will terminate! (If you are foolish enough to *not* level off first!)

This can be done in either of the slow speed configurations you have established too. The attitude will be the same and, provided you reduce power to maintain the appropriate corresponding airspeed, the ARP will still indicate where the aeroplane is going at that reduced airspeed. With a little experimenting, you will have no difficulty finding some ‘standard’ power settings to use in conjunction with these attitude, flap and airspeed combinations. The ones I used are shown in Figure Six.



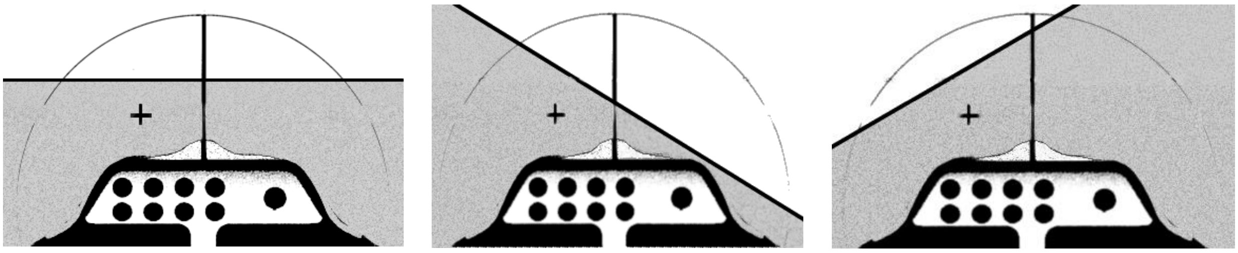
120kts, 0º Flap, 2200rpm 800ft/min | **85kts, 15º Flap, 1500rpm 550ft/min** | **70kts, 35º Flap, 1500rpm 450ft/min**

Figure Six – Descent attitudes at different speeds and flap settings.

Once again you will note that only two power settings were required, as the extra drag of full flap slowed the aeroplane without the need to alter the initial slow speed power setting of 1500rpm. Also note that the rate of descent reduces as the airspeed reduces because we are holding the same descent angle.

These low speed descent configurations are quite useful when we come to establish a landing approach, and this will be explained in Lesson Two.

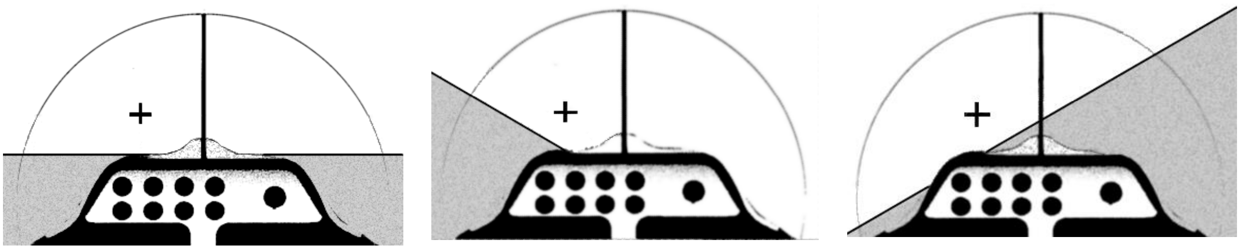
Obviously, when we turn (and reverse the turn) in any of these descent configurations the ARP will be the same distance below the horizon, as can be seen in Figure Seven.



Straight Descent **Descending Left Turn** **Descending Right Turn**

Figure Seven - Descending flight using the ARP.

What about in a climb? The climb is where the ARP has less use, but since the nose of the aeroplane is either on or above the horizon, determining the correct attitude is not so much of a problem. Even so, 'eyeballing' a point on the engine cowl immediately below the ARP will help in determining climbing turn attitudes. (Figure Eight.)



Straight Climb **Climbing Left Turn** **Climbing Right Turn**

Figure Eight - Climbing flight using the ARP.

In my training aeroplanes I had a series of dots permanently marked on the windscreen in a vertical row immediately in front of the student. This enabled him/her to determine which dot coincided with their ARP, depending upon individual head height and seat position, and to subsequently mark the ARP on this dot prior to engine start on all future flights. This made it available on take off for reasons I will be discussing in a future lesson. If you have your own aeroplane, you can permanently mark your ARP for all future flights, but you may not be able to do this in a hired aeroplane, unless you convince the owner of the usefulness of this simple little device, (refer him to this book). This is why I recommend a white board marker, not a spirit based permanent marker. You can erase the ARP after the flight if you use a white board marker but will no doubt cause the owner/operator much displeasure if you have left the ARP permanently etched onto the windscreen by using a permanent marker pen.

Over the years I have had a number of young flying instructors declare to me, that the ARP is too much of an artificiality, and that student pilots should just learn how to judge attitudes better. They may be right; but in my experience this rarely happens. With the cost of flying light aeroplanes constantly increasing, and the decreasing rate that an average private pilot can afford to fly these days, something as simple as an ARP can improve a pilot's flying accuracy significantly, and make the entire flight safer, more pleasurable and more cost effective. So why not? It only costs about $1.

The pilot of a US Navy F/A-18 uses the velocity vector to assist his approach to land on an aircraft carrier. If the light bulb in the HUD 'blows', he aborts the approach. He doesn't think it is too much of an artificiality, so why should you?

Lesson Two

The Landing Approach

The approach to land, and the technique used to accomplish a correct approach, is the most confusing part of any student pilot's flying training. The general aim is to fly an aeroplane from a point a couple of miles from the end of a runway and about 1000ft above it, to a point just above the near end of the runway, arriving there at the correct speed, so that a landing can be made from that position. Often this will also entail a 90º turn half way through the approach when flying a circuit of the aerodrome, but not always.

The student pilot has to simultaneously fly the correct approach angle, maintain alignment with the centre line of the runway, and control the airspeed such that it is the correct speed upon arrival over the runway 'threshold'. The specific techniques which are taught to accomplish all of this vary widely.

When I first tackled the problem, I was taught to fly a glide approach each time I wished to land. This meant judging the correct position in the sky to close the throttle and establish a glide, and then to control my airspeed with nose attitude and my approach angle with flaps and side slip. This all depended upon how I assessed the angle of approach I was making compared with the 'ideal' angle I had been shown by my flying instructor. Controlling the speed with attitude was not so difficult but judging the correct approach angle at the same time was. However, I found that as the ground got closer, judging which spot on the airfield the aeroplane was gliding towards did become easier. Many, many circuits of the airfield later I was 'deemed' safe for my first solo, but it took a whole lot more practice after this before I could truly say that I could make a consistent approach to land.

Assessing the accuracy of an approach angle depends upon a pilot's ability to determine the point on the airfield that the aeroplane is descending toward. This is done by finding the point in the middle of the expanding field of view we can see as we descend - which is a lot easier said than done. I have found that seeing this point out of the front of an aeroplane is quite a challenge for most student pilots. When close to the ground this expanding field of view becomes obvious and the centre of this expansion becomes equally obvious, but for a student this often only occurs in the last 100ft of the approach! Unfortunately the last 100ft is often too late in the approach to guarantee being at the right place to accomplish a safe landing. As a pilot gains experience his ability to assess this point improves, and with many hundreds of flying hours in his log book he may be able to assess this point accurately from half a mile away, but the 'journey' to this ability can be quite frustrating.

When making a glide approach the only means available to the pilot to control the airspeed is to change the attitude. Raise the nose attitude to slow down, lower the nose attitude to speed up, easy. Nowadays a modern aircraft does not make a glide approach to land; it carries a small percentage of power down the landing approach. Yet the average instructor still teaches an approach control technique that is a 'throw back' to what I was first taught! The instructor treats the approach as if the aeroplane is gliding and instructs the student to "control airspeed with nose attitude and control the rate of descent with power".

The first question which begs to be asked is this: "What the hell has the rate of descent got to do with it?" The student has enough to do without being required to monitor the vertical speed indicator. The second question is: "Why is the student expected to reverse the normal control techniques used to fly an aeroplane in all other aspects of flight?" Let me explain what I mean by that. When flying straight and level, deviations from the desired level flight path are corrected by attitude changes and speed corrections are made by adjusting the power. That is, attitude controls flight path and power controls speed. Yet, just because we are coming down a gentle 3 to 4 degree slope, all of that gets thrown out the window and this 'other' technique is supposed to be used. It doesn't make much sense does it?

Why not just point the aeroplane at the near end of the runway and control the airspeed with flap and power adjustments? The problem is, as I have already said, most pilots, including many instructors, cannot tell very accurately where the aeroplane is going when flying down this gentle 'hill' until quite late on the approach. Usually the instructors can in the last couple of hundred meters (yards) at an altitude of about 200ft. At that point they all adopt the technique I have just suggested. They may deny it, but they do.

I have, on many occasions, discussed this situation with other instructors, some quite senior, and asked them if they would lower the nose attitude to correct a 5kt under-speed situation when at 200ft? Most would say "oh no, not that late in the approach, I would just add power." Which means that by then they could see exactly where the aeroplane is going, and probably don't want to change the flight path, so the speed is controlled with power.

I am aware of a slight variation on this pseudo glide technique which involves holding a set nose attitude relative to the horizon and adjusting the speed with power to vary the 'sink' rate to arrive at the landing threshold. The main fault of this technique is again, that it assumes the student pilot can determine where the aircraft is going in order to make these power/speed adjustments. This technique is also fraught with the risk that a student who is too high on approach will reduce power to the point where the speed slips to the 'back side' of the drag curve, and the aeroplane arrives at the landing threshold with too little energy to complete a smooth touchdown. That is, it 'arrives' like a bag of wheat tossed off the back of a truck!

Before I discuss what I believe is the simplest and easiest approach technique I need to define the various flight paths to the runway that are possible. There are nine different approach paths that a student using either of the foregoing approach techniques can follow. Yes NINE! The student pilot can position his aircraft at an altitude off the approach end of the runway that is either too high or too low or at the correct height (for that distance). He can then fly the aircraft to a point well down the runway, called an 'overshoot', or he can fly to a point short of the threshold, called an 'undershoot', or he can fly it directly to a point near the landing threshold, which is okay. So we have three different possible starting points and three different possible finish points, and each of the three finish points can be attained from either of the three start points! This is nine possible combinations. The following diagrams show these nine possible approach paths, (Figure One).

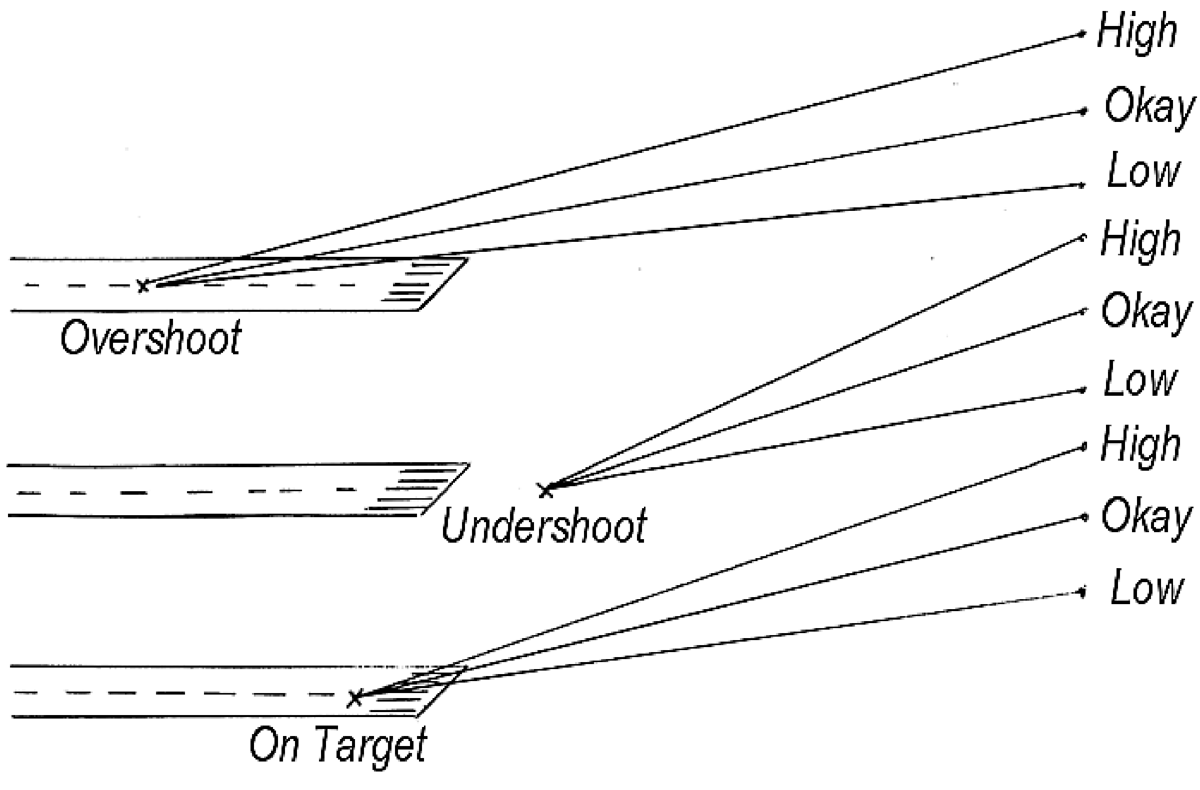


Figure One – The nine possible approach paths

Of these nine possible combinations only one is ideal (*okay & on target*) and two are, within certain parameters, acceptable. These are obviously the ones which arrive at the correct aim point near the landing threshold. The other six are unacceptable. A student pilot confused by the technique being taught to him can (and often does) oscillate between all of these nine flight paths on the one approach!!

So what is this technique that I advocate? I will re-state it.

"Aim the aeroplane at a point near the runway threshold, and control the airspeed with power".

How do we do this?

First, what is the correct aim point? To land an aeroplane we should aim to enter ground effect over the very end of the runway at the correct airspeed. This means that we have to be one wing span above the ground when crossing the end of the runway, and in order to achieve this when flying a 4º approach path, we must aim the aeroplane about 150 meters (yards) further down the runway. Of course this distance will vary with the size of the aeroplane, but 150 meters is about right for a light training aeroplane of about 30ft wingspan. So the correct aim point is a point on the runway centerline 150 meters 'in' from the threshold. (150 meters is about where the 'numbers' are on a conventionally marked, sealed runway.)

Why a 4º approach path? Well, experience has shown that 4º is a comfortable angle to approach at. Any steeper and it is hard to slow down, and any flatter and the trees get in the way. An ILS approach system used by aircraft making an instrument approach in poor visibility is normally set at 3.75º, and the visual approach slope indicator (VASI) lights you may have seen at some airports are set to this angle too. I have rounded this off to 4º. As you saw from the diagrams in Figure one, slightly steeper is okay as long as the speed can be controlled, and slightly flatter is okay too, but watch the trees.

In order to be within the 'ball park' of these acceptable angles, the aeroplane is normally positioned to start its landing approach from a distance of two miles from touchdown at a height of 1000ft (above the runway), having been configured for slow speed flight. The following diagram depicts this 'ball park' position and the approach 'funnel' it defines, (Figure Two).

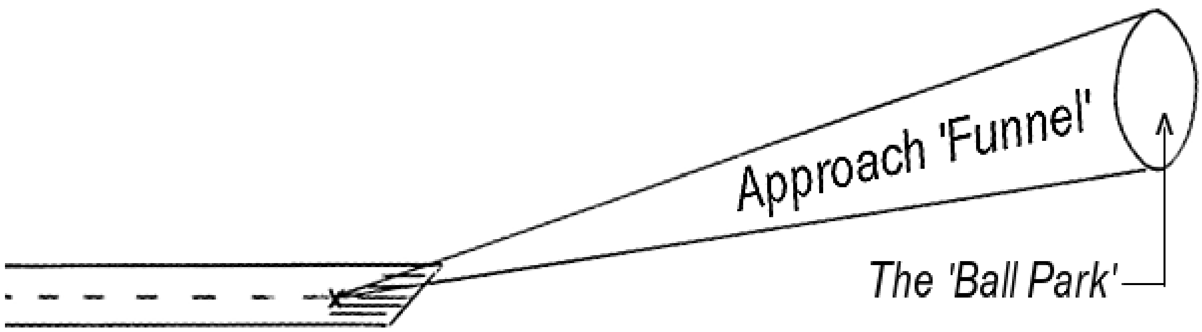


Figure Two - The approach 'Funnel'

Having entered the funnel, the aeroplane should start a slow speed descent and be aimed at the 150 meter point. How do we do this? Simple, use the ARP.

In Lesson One, we discussed the use of the ARP as a 'velocity vector' when making a descent. Remember that the initial slow speed descent configuration described in that lesson was established for a 4º descent angle, which is just what we want here. In the following diagrams I have shown the 'pilot's eye' view, when making an approach to land, using the ARP as a 'velocity vector'. I have used the speed, power and flap configurations for the Robin 2160 as an example only. Those that you determine for your aeroplane may differ slightly.

The first diagram (Figure Three) shows the aeroplane at two miles and aiming at the runway threshold.

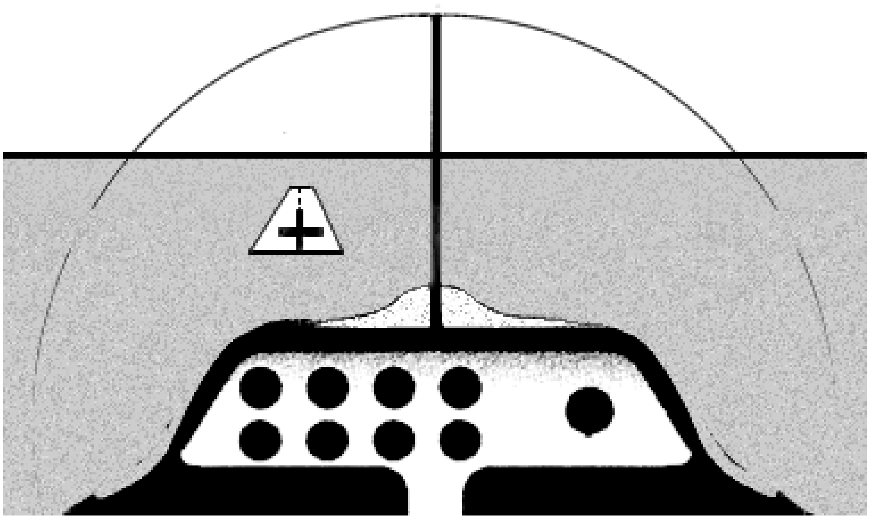


Figure Three – 2 Mile initial aim point (85kts, 15º Flap, 1500± rpm)

As long as the airspeed is maintained (at the speed we have previously determined for that flap setting), with power adjustments, the aeroplane is set to fly down the final approach like it is 'on rails'.

If the angle is a little on the steep side, a little less power will be required, and vice versa. If the aeroplane is on the correct angle of approach but the airspeed is too fast for this flap setting, the aeroplane will be going to a point on the runway beyond where the APR is aiming, and will overshoot the aim point. If it is too slow, the aeroplane will be 'sinking short' and will undershoot the aim point. Power must be adjusted as required, to maintain the correct airspeed.

By the time we have reached one mile it will be possible to refine the aim point to exactly 150 meters in from the threshold, (Figure Four).

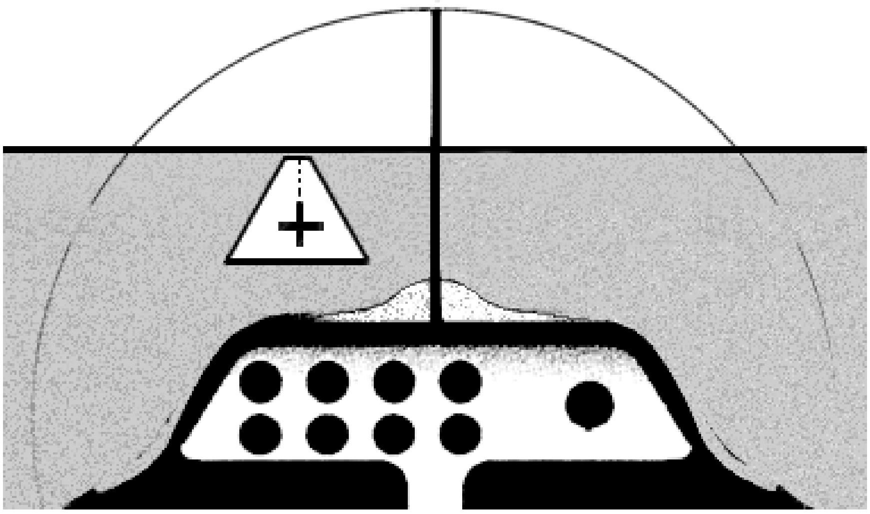


Figure Four – 1 Mile improved aim point. (85kts, 15º Flap, 1500± rpm)

Now this speed/flap configuration is too fast to land the aeroplane, so at about 200 meters from the end of the runway (350 from the aim point) it is time to 'put on the brakes' and slow down. At this point we select full flap and hold the aim point. The drag of the flap will slow the aeroplane to the correct threshold speed whilst the flap's 'lift augmentation' will offset the loss of lift associated with the reducing airspeed. This new speed/flap configuration will still enable the ARP to be used as a 'velocity vector' for the remainder of the approach, (Figure Five).

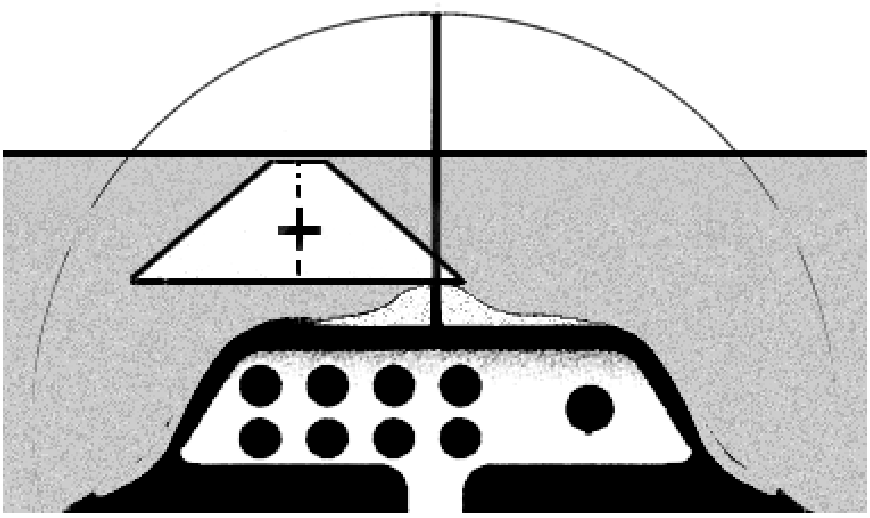


Figure Five – 200yds, Slow down point (select full flap, hold aim point)

I have found that most people can judge 200 meters reasonably accurately when this close to ground, and knowing when to 'put the brakes on' is something we do everyday when driving, so this ability translates to flying with little difficulty. This distance may vary a little for your aeroplane depending upon how effective your flaps are. (Oh! And 200 meters from the threshold is often where the airfield boundary fence is too.)

When we get to 'short final' we are, at last, close enough to see where we are going, even if we didn't have an ARP, and can therefore, make whatever last minute power corrections are necessary (if any) to 'nail' the threshold speed, (Figure Six).

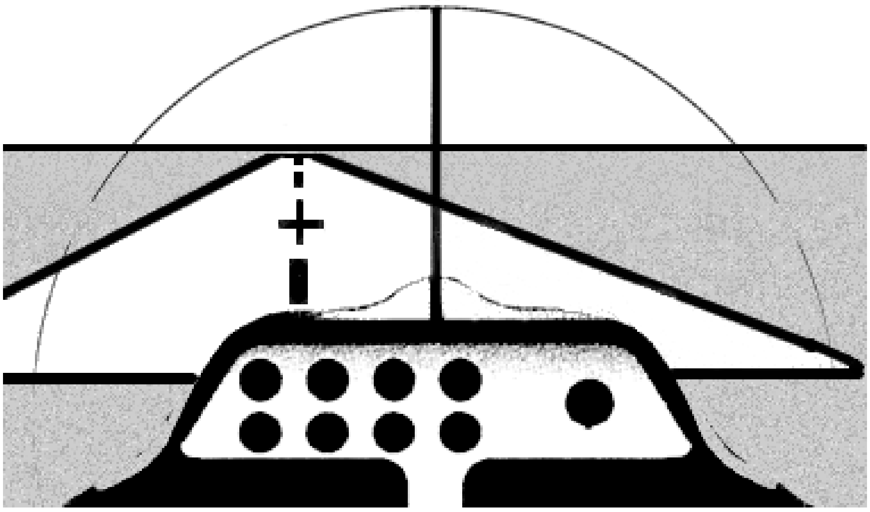


Figure Six–Approaching threshold check speed (70kts, full flap, 1500± rpm)

Finally we arrive over the end of the runway at the correct height and the correct speed, (Figure Seven). I refer to this position as the 'Key Hole'.

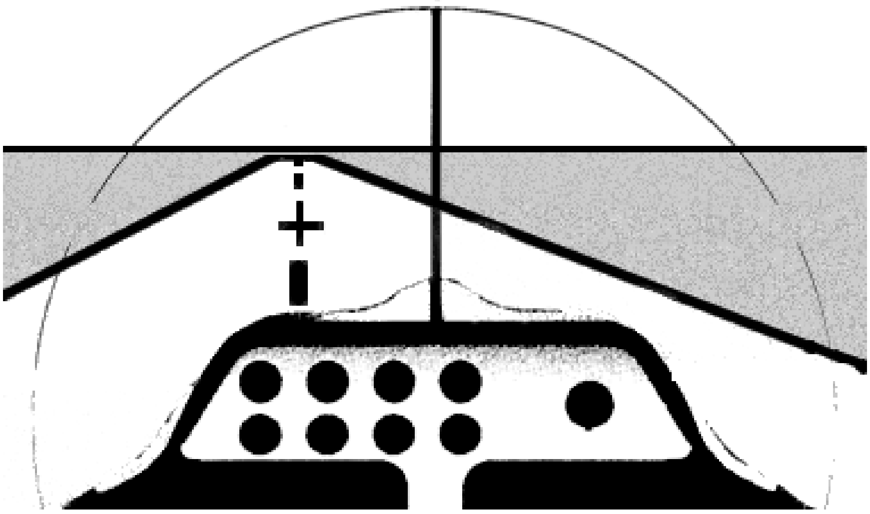


Figure Seven – Through the "Key Hole" over the threshold, on speed.

We are now entering ground effect and are perfectly set up to land the aeroplane. How we do that is detailed in Lesson Three.

So what is the correct speed to arrive over the threshold at? The simple answer to that question is 1.3Vs, that is, 1.3 times the clean, level, power off stall speed for your aircraft. 1.3Vs has been a long accepted formula for determining 'threshold speed', and provides a safe margin above the (1G) stall speed.

So common is this speed that it has even earned its own ‘V’ designation. It is called ‘Vref’, (reference velocity).

Now the flight manuals of most light aeroplanes declare an “approach speed” for that aeroplane based upon this simple formula, and this is interpreted by most flying instructors as meaning the speed at which to fly the aeroplane all the way down the two mile approach to land. Their hapless student, having just got the aeroplane stabilized on approach after wrestling with the pseudo glide technique with 15º flap (or thereabouts), is then required to lower full flap. Since the aeroplane is already on ‘approach speed’ he will then have to follow this action with a large attitude change or a significant power change to offset the additional drag he has just created, thereby destroying the stability of the approach that he has worked so hard to achieve. Often the end of the runway arrives before he has this configuration change under control, and an ‘interesting’ landing result.

The aeroplane, when it comes time to land, does not ‘know or care’ what speed it was doing one minute ago or even two seconds ago. It performs, as it enters ground effect, based upon the speed that it is doing at that instant. So the flight manual ‘approach speed’ should be interpreted as the ‘threshold speed’, that is the speed it should be doing as it crosses the runway threshold one wingspan up, (as it flys through the ‘keyhole’).

The approach technique that I have just detailed is a **constant angle variable speed approach**, as opposed to the constant speed variable angle approach technique taught by most flying instructors. The higher speed on the early part of the approach is more comfortable to fly, particularly in turbulent conditions, and holding a constant angle throughout stabilizes the approach early. In the later part of the approach when near the runway all we do is ‘put on the brakes’.

I refer you back to Lesson One - Figure Six, where you can see that, because we are holding a constant approach angle, the rate of descent reduces as the airspeed reduces. This means that any reference to ‘rate of descent’ on approach would be a huge ‘red herring’, and would only serve to confuse student pilots; so I don’t refer to it.

A few years ago, I was discussing approach techniques with a friend of mine who was a Qantas Boeing 747 check and training captain. He said that if he used the pseudo glide technique, still taught in most flying schools, to correct a 5kt approach speed error with an attitude change, the rear seats of his aeroplane would move up and down 15 feet! This would not be good for return business.

As I said at the beginning of this lesson, as a pilot gains experience his/her ability to judge the correct aim point and the correct flight path to it, improves. Ultimately these pilots will not need an ARP on the windscreen to assist this judgment (unless you are landing an F/A-18 on an aircraft carrier). Indeed there are many aeroplanes in which a cruise speed ARP is of no use on approach at all, because these aeroplanes do not have flaps. Obviously the nose attitude of these aeroplanes will be higher when slowed for a landing approach, so quite often the nose itself can be used to define a velocity vector. Some aircraft, such as the Pitts Special, have such a high nose attitude on approach that it obscures the whole runway! So these aeroplanes have to be side slipped, to get the nose out of the way, so the pilot can see where she is going. Pilots of Tiger Moths often open the side door of the cockpit so that they can lean out to gain a better view of the runway on approach to land.

How is this constant angle approach technique affected by wind? First let me remind you of the discussion about ‘wind’ from Book One. An aeroplane does not experience ‘wind’ in the same sense that someone standing on the ground experiences wind. The aeroplane’s frame of reference is the air mass in which it is flying, and the only ‘wind’ it experiences is the wind it creates by its relative motion through this air mass. It shares this air mass with other things which are moving through it too, like runways. So a runway, which is experiencing wind, can be said to be moving through the air mass too, and can, from the aeroplane’s ‘point of view’, be treated as a moving target.

A simple way to understand this is to imagine that the runway we wish to land on is an aircraft carrier moving through a calm ocean on a ‘nil wind’ day. A person standing on the deck of the carrier will experience a ‘relative wind’ equal to the speed of the ship, and will mistakenly say that an approaching aircraft has a ‘headwind’. But from the aeroplane’s point of view it is just the carrier moving in the same direction that the aircraft is moving (albeit not as fast).

When making an approach to this moving target you will have to aim the aeroplane not at where it is now, but where it will be in about two minutes time. How come? Well, assuming we are making an approach from 1000ft and the rate of descent is averaging about 500ft/min in the slow speed descent configuration, then the approach is going to take about two minutes. If we also assume that the aircraft carrier is ‘steaming’ (nuclearing?) at 10kts in the same direction as we are flying, then the landing threshold will have moved about 650 meters away from us in that time.

If we were to simply put the ARP on the aim point and hold it there, the motion of the ship would cause our approach path to progressively flatten out and the final approach could be so flat that the ‘trees’ could become a problem. Judging the final slow down point is also more difficult if we are too flat. The diagram at Figure Eight shows this flattening effect.

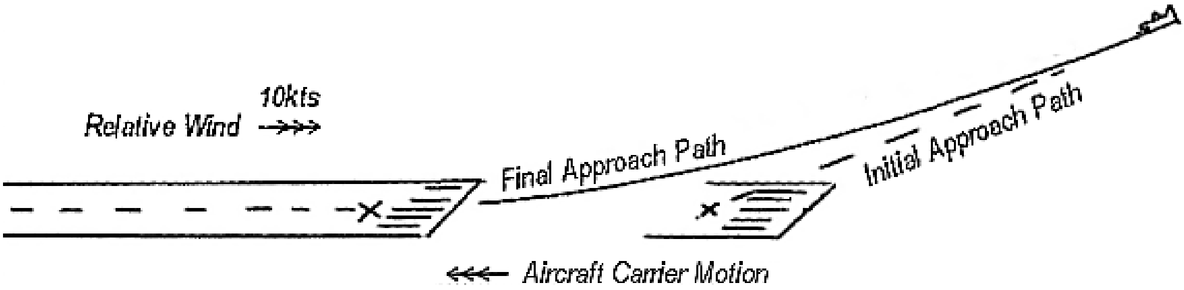


Figure Eight

In this situation we must ‘lead the target’, which means that initially we should aim the aeroplane (ARP) 800 meters down the runway (650+150) and progressively ‘drift’ the ARP back to the aim point as we progress down the approach, thereby maintaining a constant approach path to the aim point, (Figure Nine).

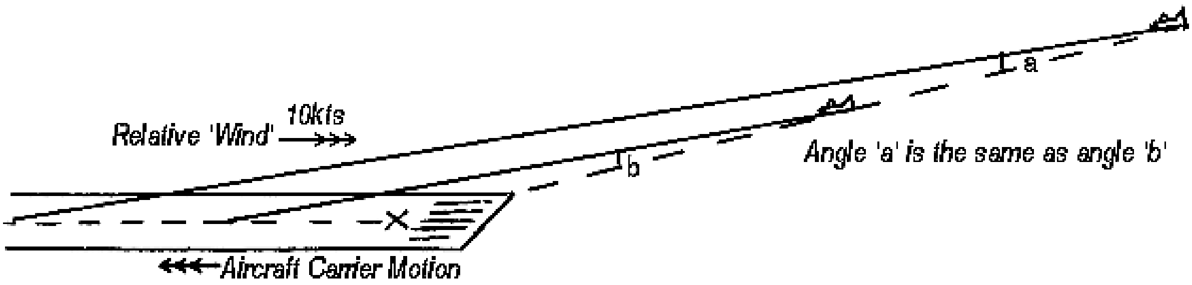


Figure Nine

You can see from Figure Nine that the ARP line is moving back toward the aim point as the aeroplane gets closer to the threshold. You should also note that the *angle* between the ARP line and the flight path to the aim point is constant. This means that it will not be necessary to consciously move the ARP back along the runway if you can pick a point on the windscreen a little below the ARP and hold it on the aim point. The angular difference between this point and the ARP will subtend a decreasing distance along the runway as the aeroplane gets closer to the threshold, thereby automatically drifting the ARP back. Figure Ten is a ‘cockpit’ view of this technique.

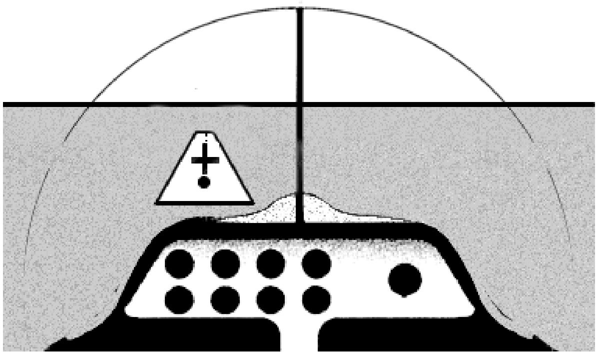


Figure Ten (a) One mile out

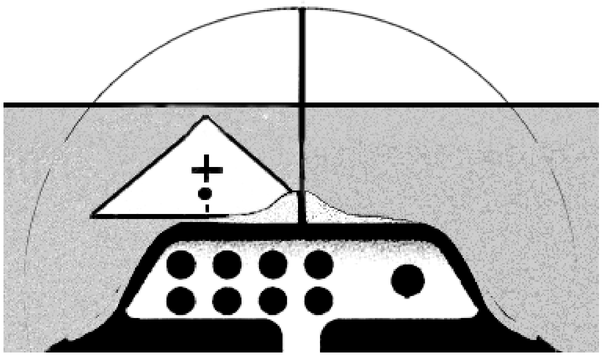


Figure Ten (b) Half mile out

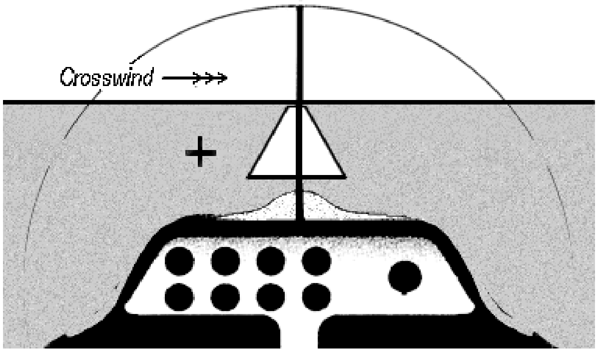
Note that the dot below the ARP is in effect an ‘adjusted ARP’, and is on the aim point throughout the approach, whilst the ‘primary ARP’ moves back down the runway as the aircraft gets closer to the threshold.

Remember I said in lesson one that I had a number of attitude reference dots marked on my windscreens? Well here is a photograph of them.

Attitude reference dots on the windscreen

Each of these dots was spaced such that the angular distance between them was equal to 10kts, so all the pilot had to do was put the dot below the ARP on the aim point to allow for a 10kt ‘headwind’ or two dots below for a 20kt ‘headwind’. Now I didn’t plan it that way initially, I simply put them one inch apart and I ‘lucked in’ the right angles for my aeroplane. Try putting some dots an inch apart below the ARP on your windscreen and see how they work out for you, you can always adjust them once you have gained some experience using them in different headwinds.

What about a crosswind? If you are a ‘crab down final and kick it straight at the last minute’ pilot then the ARP will have to be positioned abeam the aim point by an amount equal to the drift angle. It will appear to be positioned quite wide of the runway initially, but as you track (crab) your aeroplane down the runway centre line, and draw closer to the threshold, it will automatically move closer to the runway. See Figure Eleven.



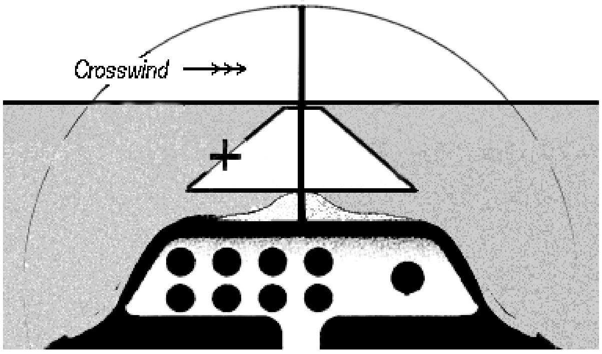
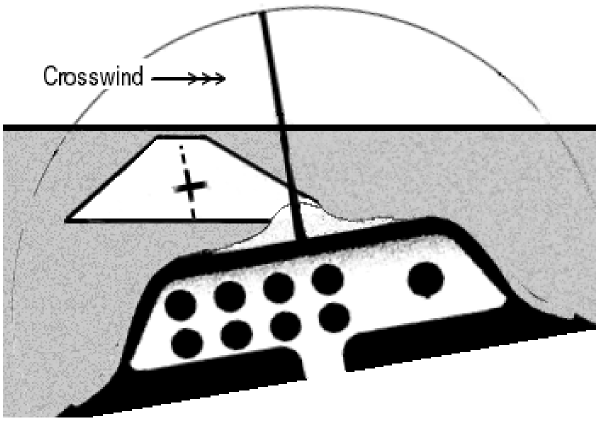


Figure Eleven (a) **Figure Eleven (b)**

If you eliminate the effect of the drift angle by side slipping into the crosswind as described in Book One - Lesson Twelve, the ARP can once again be positioned on the aim point as shown in Figure Twelve, for both left and right crosswinds. The small angle of bank required does not change the use of the ARP as a velocity vector because it is indicating the aircraft flight path, and aeroplanes roll (bank) around their flight path as detailed in Book One - Lesson Six.



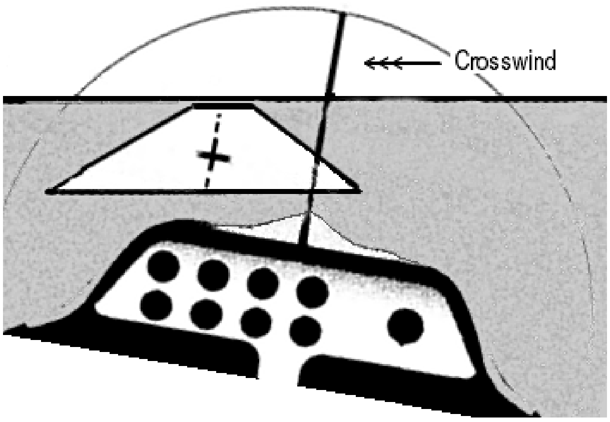


Figure Twelve (a) **Figure Twelve (b)**

If your preferred crosswind approach technique involves a mixture of crab and side slip, then with a crosswind from the left, your initial picture will be similar to that shown in Figure Eleven (a) and will then become that shown in Figure Twelve (a). For a crosswind from the right the opposite would apply.

By using either or all of these ‘wind’ correcting techniques based upon the constant angle approach I have detailed in this lesson, you and your aeroplane will fly through the ‘Key Hole’ on speed. This will not land the aeroplane for you but will give you an accurate and consistent start to learning the art of landing.

Which is the next lesson…………

Lesson Three

Landing

"Having passed through the 'Key Hole' at the correct threshold speed (1.3 Vs), the aircraft's descent is smoothly arrested, and the main wheels are rolled onto the runway without the slightest bump". That's the way we would like every landing to be, but it doesn't always turn out that way. A good, consistent, smooth landing is half technique and half art. I will discuss the technique - the art, the feel, and the finesse, will then come with practice, lots of practice.

A good landing can be divided into four parts which should form a seamless and continuous process. They are:

1. The 'Flare' (sometimes called the 'Roundout')
2. The 'Hold Off'.
3. The 'Touchdown'.
4. The 'Roll Out'.

Figure one shows the first three of these parts.

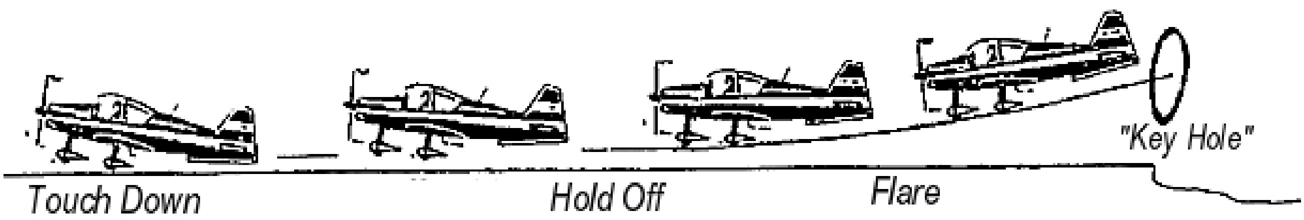


Figure One - Flare, Hold Off, Touch Down.

I will discuss each one in turn.

The 'Flare' is the name given to the action of arresting the aeroplane's descent as it enters ground effect and bringing it to level flight, with the wheels about one foot (30cm) above the runway. This is achieved by increasing the angle of attack and smoothly bringing the attitude to 'ARP on the horizon', as shown in Figure Two. (The aerodynamics of this process was detailed in Book One - Lesson Six, Manoeuvring.) At some point during the flare the aviator should also reduce power to idle by closing the throttle, but exactly when to do this depends upon the exact speed at the 'keyhole' and the type of aeroplane, and is discussed in more detail in Annex A.

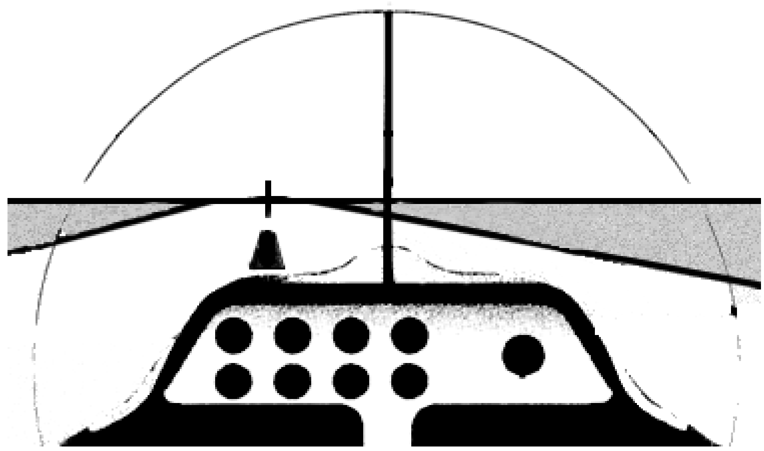


Figure Two - Attitude at the conclusion of the Flare

The rate at which the attitude is changed is critical. Too rapid and the aeroplane will level off too high. Too slow and the wheels will ‘arrive’ prematurely. Judging this is the first part of the ‘Art of Landing’.

If the flare rate has been too rapid, leaving the wheels too far from the ground, it is possible to rectify the problem by pausing in this level attitude for a second or two to allow the aeroplane to settle to the correct height as the speed reduces. Caution should be exercised when doing this because the attitude will no longer be correct for the speed when the aircraft has settled to the correct height so it may continue on down and the wheels could touch down prematurely. Adding a ‘trickle’ of power can cushion this premature ‘sink’ to the runway, but this will depend upon what we have done with the throttle at the commencement of the flare as discussed in Annex A. Better to get the flare rate correct to begin with.

If the flare rate has been too slow it is possible for the nose wheel to contact the runway first. Because the nose wheel is ahead of the centre of gravity this will cause the nose to pitch up sharply, increasing the angle of attack and the aircraft will ‘bounce’ back into the air. The pilot is then likely to move the stick forward to stop this bounce, but will usually react a split second later, when the aircraft was returning to earth anyway, thereby exacerbating the next bounce, and so on. The term used to describe this seemingly never ending series of oscillations and bounces down the runway is, ‘Pilot Induced Oscillations’ or PIO’s for short. It has also been called the ‘JC manoeuvre’ because of the common sacrilegious utterance of most pilots upon encountering this situation.

PIO’s or JC’s can damage the nose wheel of the aeroplane and should be avoided by adding full power and climbing away from the top of the first bounce, that is, ‘going around’.

If you are flying a Tail Dragger, the main wheels are also ahead of the centre of gravity whilst the tail wheel has to settle a lot further, thereby causing a gross attitude and angle of attack change, so the JC’s, which result from a premature contact with the earth in a tail dragger, really earn their name and can become quite wild. Don't try to tame them…..go around.

So much for the first part, so now to part two, the 'hold off'.

Having achieved level flight one foot above the ground the aircraft is held at this height as it slows. This of course will necessitate increasing the angle of attack by raising the nose attitude progressively as the speed diminishes. This attitude adjustment should be a seamless continuation of the attitude adjustment during the flare, and should be continued at the correct rate until the correct landing attitude is attained. But what is the correct rate and what is the correct 'landing attitude'?

The correct rate to raise the nose during the hold off, will depend upon how rapidly the aeroplane decelerates in ground effect, and obviously should be a rate which matches this deceleration and holds the wheels one foot above the runway. Judging this is the second part of the 'Art of Landing'. If the nose is raised too slowly, once again the wheels can arrive prematurely. This could result in a 'skip' as the undercarriage suspension rebounds, or a 'three wheeler' landing. If the skip is only slight continue with the hold off to the correct attitude, but if the three wheels stay on the ground, freeze, don't continue raising the nose, as the aeroplane will fly off the ground again and a PIO could result. A 'three wheeler', whilst not a perfect landing, is better than the alternative. Give yourself a mental slap on the wrist and try to do better next time around.

If the nose is raised too rapidly, the aeroplane will 'balloon' back up into the air and we will be in the same position we would be in if we had flared too rapidly. If the balloon is slight, pause in whatever attitude you are in until the aeroplane starts to settle again, and then continue the hold off. If the balloon is large, the aeroplane will become too high and too slow, and will then develop a high 'sink' rate and arrive like the proverbial bag of wheat tossed off the back of a truck. Do NOT lower the nose to stop this balloon, as all you will achieve is to arrive like a bag of wheat on the nose wheel! Apply full power and go around.

What about the 'landing attitude'? If you are flying a tricycle undercarriage aeroplane the aim is to touchdown on the main wheels with the nose wheel clear of the ground. If flying a tail dragger, the aim is to touch down on the main wheels and the tail wheel simultaneously. Let's discuss tri-gear aeroplanes first.

The landing attitude of a tri-gear aeroplane depends upon how 'deep' the wing is in ground effect. If the aeroplane has a low wing it will be experiencing a significant ground effect 'cushion' so the nose attitude does not have to be too high. Nose on the horizon is usually sufficient, as shown in Figure Three.

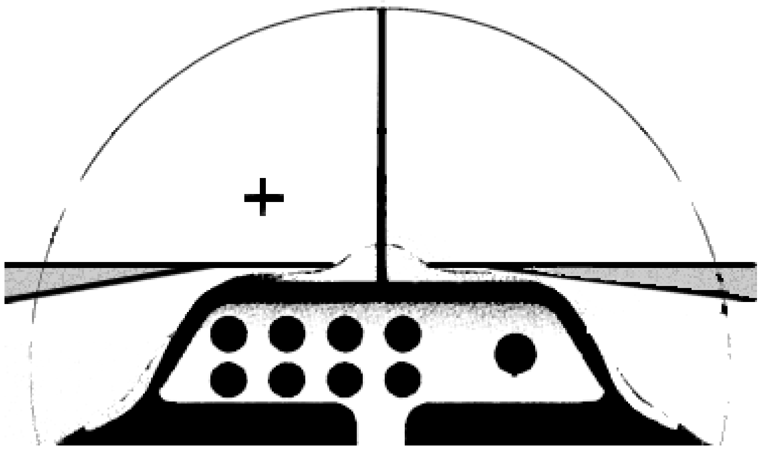


Figure Three - Landing Attitude for Low Wing Tri-Gear Aeroplane.

If the aeroplane has a high wing it will be experiencing less than half the ground effect cushion of the low wing aeroplane (Book One - Lesson Ten), so it should be held off to a slightly higher attitude for landing, as shown in Figure Four.

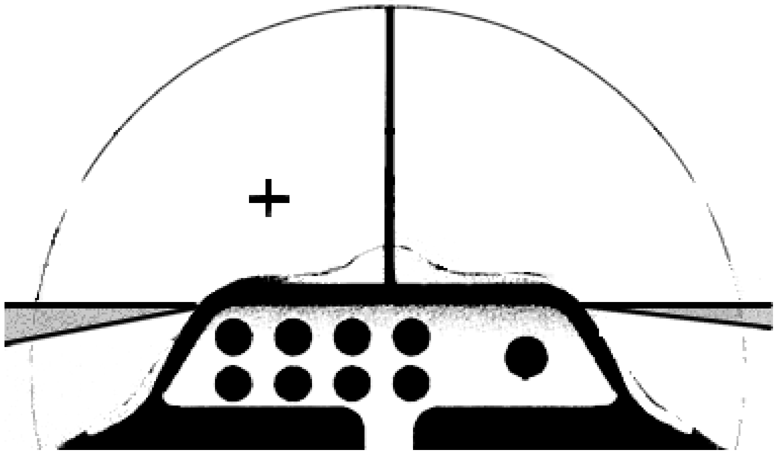


Figure Four - Landing Attitude for High Wing Tri-Gear Aeroplane.

Now I must emphasize that these landing attitude pictures are generalizations. The individual eye height and seating position of each pilot will alter them slightly, as will the length and slope of the aeroplane's engine cowling. Have your flying instructor show you the landing attitude which suits your aeroplane.

There may also be other factors which determine the correct landing attitude of a particular aeroplane. The Sia Marchetti SF-260 which I operated for many years had a very long nose gear leg, and had to be held off to a higher than normal landing attitude for a low wing aeroplane to avoid contacting the ground nose wheel first and starting a PIO. By contrast the Robin 2160 has a large ventral fin and should be limited to the attitude pictured at Figure Three to avoid scraping the fin on the ground! (Note the 'tail skid' in the photograph at Figure Three.)

Many flying instructors tell their students to hold off until the aeroplane stalls. This is a vintage Tail Dragger technique and is not necessary for a modern aeroplane. Indeed they will also say that the wing is stalled when the 'horn' sounds, which of course, as we have already learned from Book One, is not true. Often, just as the correct landing attitude for a particular aeroplane is attained, the stall horn may start to 'beep', but this is not what we should be aiming for.

What about the landing attitude for a Tail Dragger? As I have said, the aim is to touch down on all three wheels simultaneously; this has been traditionally called a 'Three Pointer'. This three point attitude is easy to determine, and it can be determined before take off. Once lined up on the runway prior to rolling for take off, note where the horizon is in relation to the nose. This is the three point landing attitude. On older style tail draggers this attitude will be virtually the same as the level stall attitude, but on modern tail draggers it will be a slightly 'flatter' attitude. It doesn't matter, what you see before rolling is what you 'shoot for' on landing. Refer Figure Five.

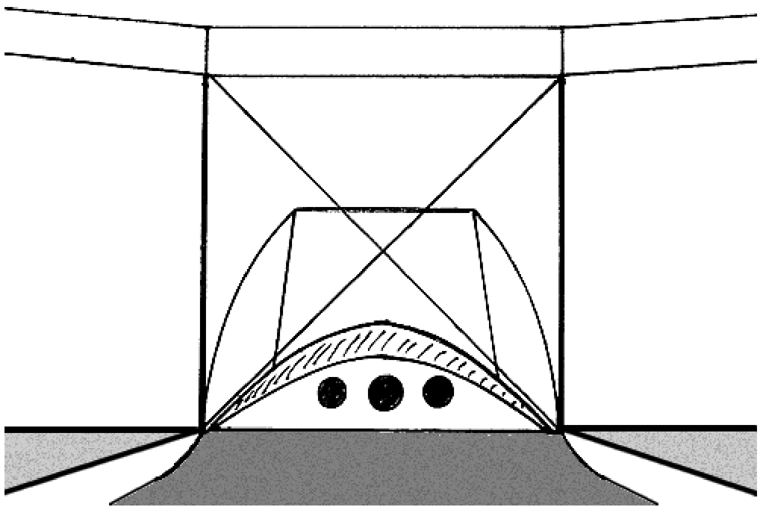


Figure Five – Tail Dragger Landing Attitude (Tiger Moth).

Achieving the correct landing attitude in a tail dragger is more critical than a tri-gear aeroplane. If too flat the main wheels will settle on first causing the tail to drop, the angle of attack to increase and the aeroplane to fly off the ground again. If the attitude is too high the tail wheel will touch first and pitch the aeroplane forward onto the main wheels causing a bounce. The severity of either of these two possibilities depends upon how inaccurate the landing attitude was. Some tail dragger pilots prefer to touch down slightly tail wheel first…slightly. This causes the angle of attack to reduce slightly as the aeroplane pitches forward slightly, onto its main wheels, helping it to 'stick'. The operative word here, in case you hadn't noticed, is slightly; otherwise all hell breaks loose!

Figure Six is an external view of a Pitts S2S in the correct landing attitude just prior to touchdown. The fuselage is 12º from horizontal; therefore the wings, due to their incidence, are at an angle of attack of 13.5º, which is much less than their critical angle of attack.

Figure Six – Pitts S2S in the 'Three Point' Attitude.

There is an alternate landing technique which can be used in a tail dragger called a 'wheel' or 'wheeler' landing, where the aeroplane is landed on its main wheels only, with the tail wheel still clear of the ground. This technique demands a little more finesse and I will discuss it in more detail in Annex B.

So what do we do when we attain the correct landing attitude one foot off the runway? *Hold it*, that's right, just hold that attitude. This is the beginning of the touchdown phase. As the aeroplane slows some more it will smoothly settle the final one foot onto the runway, all by itself!

Once the main wheels of a tri-gear aeroplane have touched down, because the centre of gravity of the aeroplane is ahead of the main wheels, it will naturally want to pitch nose down. This is one of the advantages of the tricycle undercarriage configuration, in that it will 'automatically' reduce the angle of attack of the wing, thereby helping the aeroplane to 'stick' to the ground.

However, we still have to 'land' the nose wheel smoothly. I have seen pilots at this point just relax the back stick and let the nose wheel come crashing down and I have seen pilots try to hold it off forever, or at least until, despite their efforts, it comes crashing down anyway. Somewhere between these two extremes is ideal. A smooth nose wheel landing is easily achieved if we do nothing! Just freeze on the stick (or wheel), until the nose wheel 'auto lands'. How does that work? Well obviously as we achieve the correct landing attitude just prior to touchdown the stick is well back and the elevators have a large negative incidence. Once the main wheels have touched and take up the weight of the aeroplane the nose will start to pitch down. As this happens the elevator presents itself to the airflow at a greater and greater negative angle of attack, offsetting the effect of the reducing airspeed and producing a constant download on the tail, thereby cushioning the final nose wheel touchdown. (Figure Seven.)

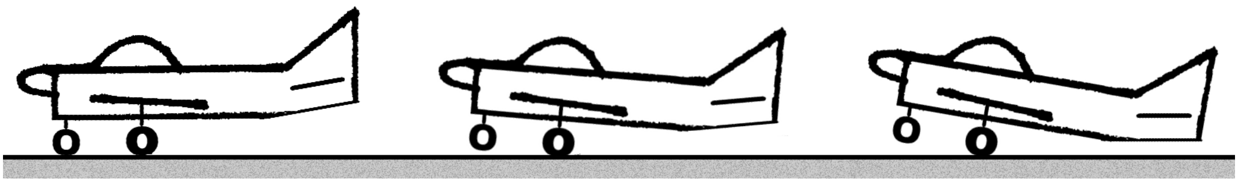


Figure Seven – Elevator angle to airflow during nose pitch down.

Once all three wheels have 'landed' the elevator can be relaxed to neutral for the roll out. So, let's now make a quick recapitulation of the touchdown technique of a tri-gear aeroplane:

Hold the correct landing attitude until the main wheels land, and then hold the stick position until the nose wheel lands.

That doesn't sound too hard, does it?

If we have just achieved a three point landing in a tail dragger all three wheels are already in contact with the ground so simply move the stick fully back to ‘pin’ the tail wheel down, thereby assisting the steering during the roll out.

What if we are landing with a cross wind? Regardless of whether we have crabbed or side slipped down the approach, the final touch down should be made in a side slip. If we have side slipped all the way down the approach, or have set up the side slip before the flare, then all that I have said previously still applies and in addition, the aeroplane will also have the appropriate amount of bank applied throughout the landing process. If we have commenced the flare whilst still crabbing then it will be necessary to yaw the aircraft into line with the runway and apply the correct amount of side slip during the hold off, which is, as I have said in Book One, a more demanding co-ordination exercise for a student pilot. We should still hold off to the correct landing attitude and at that point, regardless of how we have dealt with the crosswind up until then, we will have some bank applied at touchdown as shown in Figure Eight.

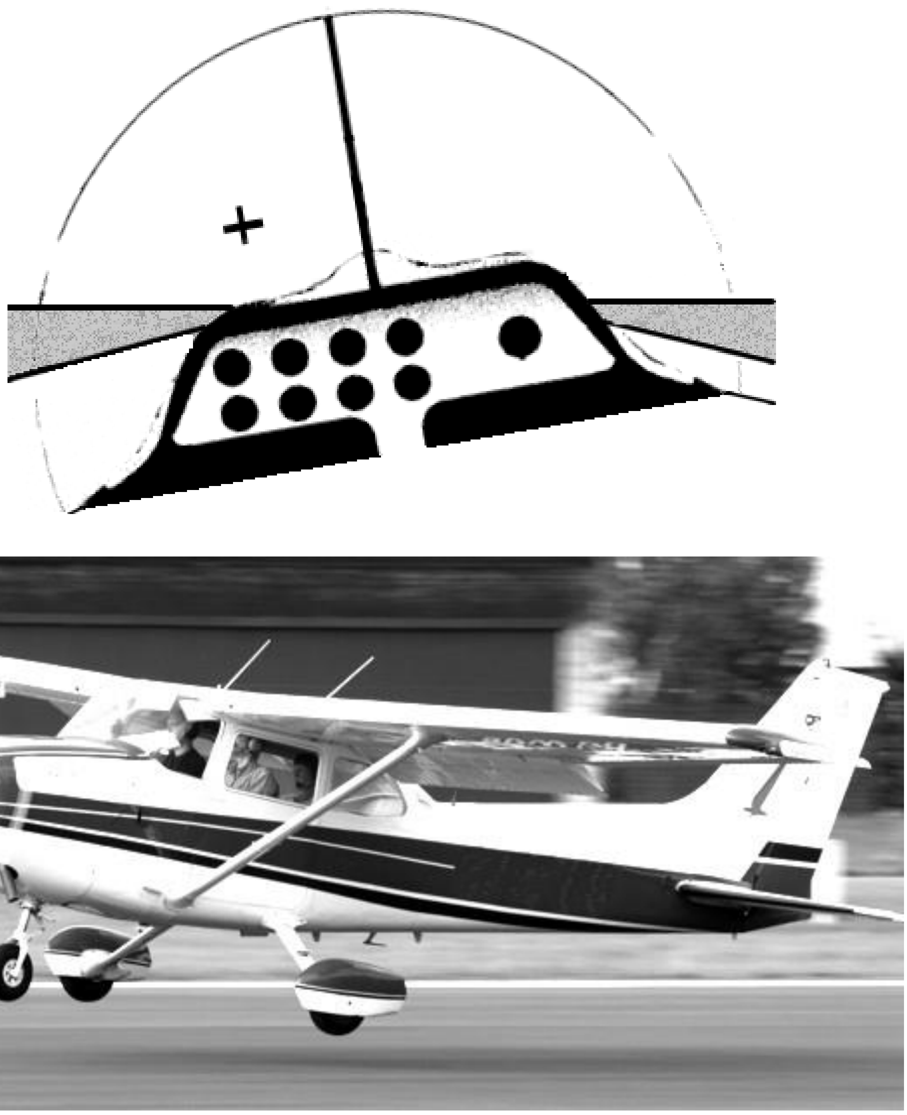


Figure Eight – Landing Attitude whilst Side Slipping in a Cross Wind

After touchdown hold both elevator and aileron input until all wheels have landed and keep straight with rudder whilst they are doing so. Then we may relax the elevator but maintain the aileron input throughout the roll out. (In strong crosswinds it may even be necessary to increase the aileron deflection as the aeroplane slows in order to keep the 'into-wind' wing down, which helps us maintain directional control.)

We have now reached the final phase of the landing, the 'roll out' phase, but don't relax yet "coz it ain't over yet!"

If I were to build a light metal frame, supported by three small wheels in a tricycle configuration with only the front wheel steerable, sit you in it, and ask you to steer it with your feet whilst I propelled you down the road at 120 kilometers per hour (60kts), you might decide that the undertaking was rather risky. But that is exactly what you are doing immediately after touchdown in a tri-gear light aeroplane! So stay focused, use the correct technique and wear the correct footwear. Footwear! What has that got to do with it? If you are in the habit of wearing solid work boots or thick soled shoes whilst flying, you will not have a very good 'feel' when working the nose-wheel steering pedals (rudder pedals) of an aeroplane, and will probably over-control the steering. If you are learning to land a tail dragger, very thin soled shoes are a must. I would have my Pitts S2A students wear only their sox for the first few sessions, for reasons I will explain shortly.

I still remember with a smile, one of my Pitts students turning up for a lesson one day after I had chided him for wearing too heavy footwear on the previous flight, resplendent in nomex flight suit, flying helmet and gloves and wearing fluffy pink bunny slippers.

So what is the correct technique? Simply stated, "look where you want to go", otherwise you will go where you are looking! I remember watching my six year old daughter practicing riding her new bicycle on a large grass area near where we lived. In the middle of the area was a tree, which she managed to run into several times because she kept looking at it! I have sat with student pilots who weaved all over the runway because they were not focused on the centre line of the runway in front of the aeroplane, but were looking elsewhere or trying to do other things in the cockpit, which could have waited a few moments.

Many years ago I undertook an advanced driving course, which focused on emergency handling techniques. One aim was to avoid running into or over obstacles which suddenly presented themselves in front of the car. The simple 'trick' was to look at, and focus on, the escape route, and not look at the obstacle. It was amazing the number of times the obstacle 'dummy' was 'killed' because drivers were looking at it, just like my six year old daughter and the tree. So during the roll out, focus on the runway <u>centerline</u> at least a couple of hundred meters (yards) ahead of the aeroplane. This simple trick will help you keep the aeroplane straight as it rolls down the runway after touchdown.

Finally, use only smooth application of brakes in the later stage of the roll out, and only if necessary. Aeroplanes only have little brakes, which are easily overheated if used too aggressively.

The roll out of a tail dragger is a bit trickier. First, the tail dragger configuration is statically unstable because the centre of gravity is behind the main wheels, and wants to overtake them! Keeping a tail dragger straight is like balancing a broom vertically on the palm of your hand (brush end up). You have to make continual and rapid movements of your hand to keep the brush end steady and prevent it from falling over. If you let a tail dragger start to veer or swing the centre of gravity will overtake the main wheels and cause the whole aeroplane to swing around quite rapidly into what is commonly called a 'ground loop'. To prevent this you have to make continual and rapid foot movements on the steering pedals to keep the aeroplane dead straight. I call this 'tap dancing on the pedals'; it needs a sensitive touch, hence the sox.

Ground looping a tail dragger, especially at high speed can cause considerable damage to the aeroplane, and is to be avoided if at all possible. I have seen ground looping tail draggers collapse their undercarriages and break their wings off. Not a pretty sight.

The second problem is that because it is a tail dragger, the nose obstructs the pilot's forward view during the roll out! (Take another look at Figure Five.) This means that achieving the previous requirement of keeping dead straight is especially difficult. I have heard it likened to driving your car down a narrow driveway at high speed in reverse with the boot lid up. (That's trunk lid for my American readers.) Not all tail draggers are quite as difficult as this, but I have flown a few that are.

So how do we keep a tail dragger straight during the roll out? The answer and explanation to this question is rather lengthy and since 99% of the readers of this book will be, or have been trained on tri-gear aeroplanes I will relegate it to Annex C in order not to prolong this lesson for the majority of readers.

What about taxiing back to the parking area after landing? Normally in light to moderate wind conditions this is no problem for the pilot of a tri-gear aeroplane. The stick or wheel should not be abandoned but held in a neutral position so that stray wind gusts do not bash the control surfaces against their 'stops' and damage them. But more attention should be given to the positioning of the stick when taxiing a tail dragger as it will be more susceptible to directional control difficulties in all but the lightest of winds. I discuss the correct positioning of the stick when taxiing a tail dragger in Annex D.

One final note on tail draggers. From what you have read in this lesson and what you will read in Annexes B, C and D you could be forgiven for wondering why anyone in there right mind would bother flying one, and why they are still produced. The simple answer is that flying is not just about landing; fewer wheels sticking out the bottom of the aeroplane generate less drag and weigh less, so the aeroplane performs better in the air. Take a look at all high performance aerobatic aeroplanes and you will not see a tri-gear aeroplane amongst them. Also the tail dragger configuration is more robust and is better suited to 'off airfield' operations and the propeller can be kept further from the ground during these same off airfield ops. Bush pilots favor them and aerobatic pilots favor them.

Oh! In case you were wondering, my daughter grew up to become an accomplished aerobatic pilot, and never once ran her Pitts off the runway.

List of Annexes to the lesson on Landing:

Annex A. When to close the throttle

Annex B. The Tail Dragger 'Wheeler' landing

Annex C. Keeping straight in a Tail Dragger

Annex D. Taxiing a Tail Dragger on a Windy Day

Annex A

When to close the throttle

In all of the discussion of landing technique it is assumed that the aeroplane has reached the ‘keyhole’ at the correct threshold speed. But what if you have misjudged the approach and arrive a little ‘hot’? In this case the pitch rate during the flare will have to be slower to avoid ‘ballooning’, the hold off will be more protracted, and the touchdown will occur further down the runway. Closing the throttle a small distance before passing through the keyhole can, depending upon how fast you are going, help rectify this situation. On the other hand if the aeroplane is a little slow it would be foolish to close the throttle at the commencement of the flare as the wheels would certainly ‘arrive’ before you had attained the landing attitude. In this case the power should be carried through the flare and the throttle only closed when level flight in ‘ground effect’ is achieved.

But assuming that the correct threshold speed is attained there are still a couple of things which influence exactly when the throttle should be closed. The first is ground effect and the second is aircraft mass. As I mentioned in the main text, the position of the wings will determine how much ground effect is experienced by the aeroplane. During the flare the wings of a low wing aeroplane will experience ground effect higher and sooner than those of a high wing aeroplane so the throttle can be retarded at the commencement of the flare, whereas the throttle of a high wing aeroplane should be retarded toward the end of the flare. Now the entire duration of the flare is only 2-3 seconds so there is very little difference in these two situations but we are now talking about the art of finessing the landing.

There is one other aspect of this question which affects high wing aeroplanes and that is the change of trim when the throttle is closed. On high wing aeroplanes the thrust line is normally below the drag line causing a slight nose up pitch tendency when power is increased, and a slight nose down pitch tendency when power is reduced. These tendencies are normally offset with a small elevator input, but during the flare, if the throttle is retarded too soon or too abruptly, the nose down pitch trim change can slow the rate of nose up attitude change required. This can result in the wheels arriving before the pilot intends.

Perhaps a more significant factor in determining when to close the throttle is the aircraft’s mass and therefore its inertia. A light aeroplane will have low inertia and will slow quite rapidly once the throttle is closed. This will leave the pilot little time to stop the descent and establish the correct landing attitude. Often in this case the wheels will also arrive prematurely. Pilots used to normal GA aeroplanes will notice this effect when they first attempt to land an ultralight aeroplane. Carrying the power right through the flare and into the hold off, and only closing the throttle when the correct landing attitude is approached, will overcome this low inertia problem.

I often used this technique when teaching ‘three pointers’ in Tiger Moths as it prolonged the process and allowed the student time to judge the landing better. As their performance improved the power was reduced to idle earlier and earlier until eventually the throttle was being closed at the commencement of the flare, which is normal for a Tiger Moth.

So what is the correct point to close the throttle in a low wing low inertia aeroplane versus a high wing high inertia aeroplane? There is no simple answer to this, but knowing the effects of these variables will equip you to go out and experiment in a systematic way, rather than just haphazardly throwing the aeroplane at the ground and hoping for the best. Of course all of this experimentation presupposes that the aeroplane arrives at the keyhole at the correct speed every time, so the old saying that a “good approach makes for a good landing” is particularly true when you are first learning the art. The use of an ARP, as described in Lesson Two, will greatly assist in this.

Annex B

The Tail Dragger 'Wheeler' landing

Since a tail dragger in the three point attitude sits on the ground at quite a high angle of attack, it is vulnerable to directional control difficulties during the roll out in a crosswind. Couple this with its inbuilt 'ground loop' tendencies and a cross wind landing in a tail dragger becomes quite a challenge. The 'wheeler' landing can help alleviate this challenge somewhat by enabling the pilot to control the angle of attack during the roll out, but this technique has its own challenges.

A wheeler landing is achieved by rolling the main wheels of a tail dragger onto the ground in a reasonably flat attitude with the tail wheel still well off the ground. Bearing in mind what I have said in the main text of this lesson about the result of the main wheels arriving prematurely, how do we achieve this?

The approach and flare are the same as I described in the main text, but once the descent rate is arrested the rate of change of attitude during the hold off is deliberately slower than necessary to hold height, and the main wheels are allowed to gently settle to Earth well before the three point attitude is reached. This takes a degree of finesse to avoid setting up a 'JC'! (See Figure One. Note the elevator position.)

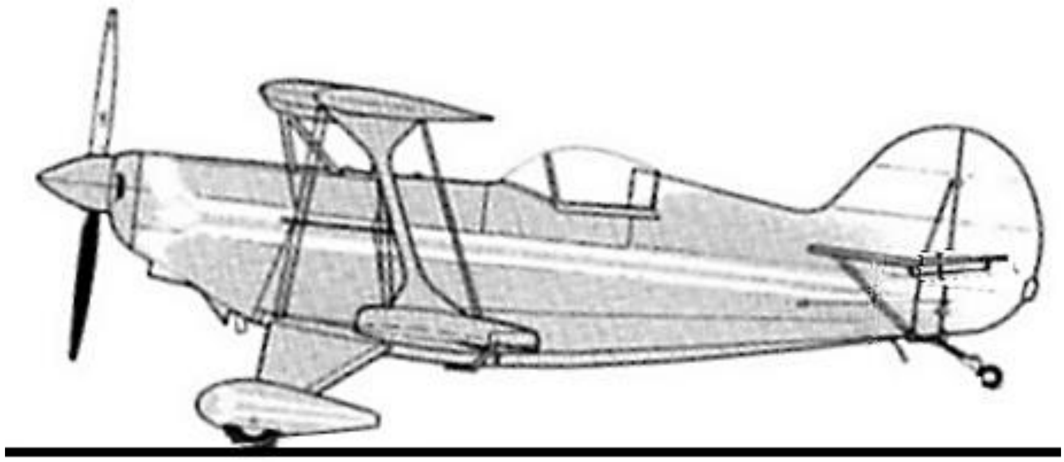


Figure One – Main wheels gently 'rolled' onto runway.

Once the wheels roll onto the runway the stick is moved forward a little to lift the tail and reduce the angle of attack a few degrees, thereby helping the aeroplane 'stick'. Care must be taken not to push the stick too far forward or the aeroplane can be 'stood on its nose' and damaged, so easy does it. (See Figure Two. Note the elevator position.)

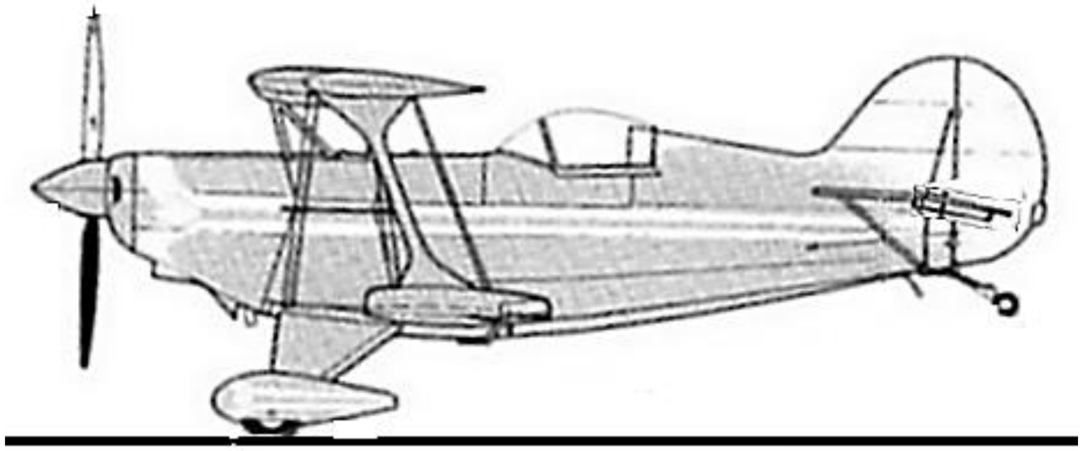


Figure Two – Tail lifted a little to 'pin' main wheels onto runway.

During the rollout the rate the tail is lowered to the ground is controlled by judicious use of forward stick (down elevator) such that the angle of attack of the wing is never so great that the remaining airspeed will cause the aeroplane to fly off again. Finally, once the tail wheel has been landed, the stick is moved fully back to pin it down and the remainder of the roll out is controlled in the same way as for a 'three pointer'. (See Figure Three. Note the elevator position.)

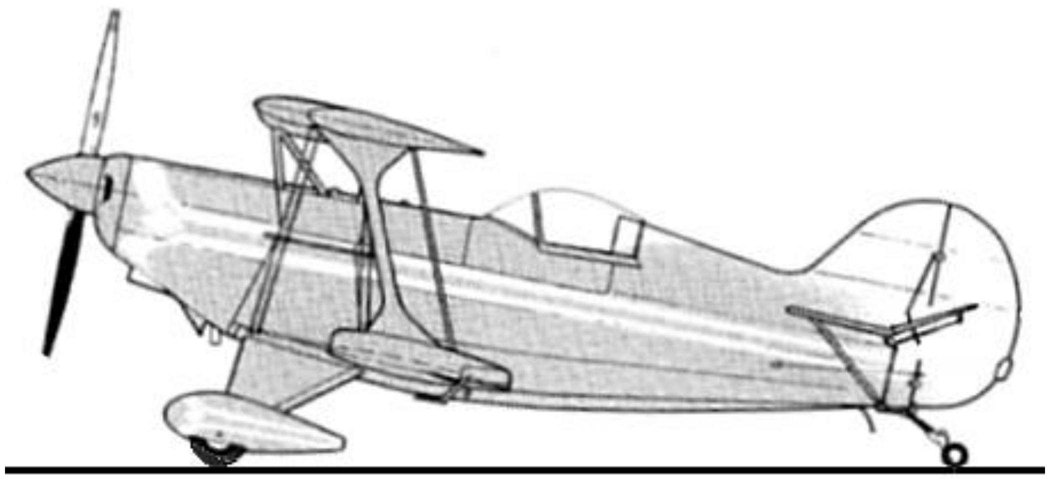


Figure Three – Once tail has 'landed', stick fully back.

This technique when used in a cross wind enables the aviator to hold the tail up and keep the wings at low angle of attack, and also maintain improved airflow over the rudder, thereby helping maintain directional control until the speed diminishes to the point that the aeroplane can be controlled with the tail wheel on the ground. I remember watching a good friend of mine regularly land his Tiger Moth in crosswinds up to 20kts by lifting the tail to slightly beyond the level attitude after wheeling it on, and holding the tail up there with progressively more forward stick until it was fully forward. The tail would then 'auto-land' as the speed diminished with the stick held fully forward (in a manner similar to that which I described for landing the nose wheel of a tri-gear aeroplane). By the time the tail skid finally touched down the aeroplane had hardly any remaining forward speed.

I must sound a note of caution at this point. I have seen, and sat in the cockpit with, pilots whose idea of doing a 'wheeler' in a tail dragger is to flare to level and then shove the stick forward to forcefully put the main wheels on the ground and pin them there! At best this punishes the undercarriage unnecessarily and at worst, if the pilot has flared too high to start with, can crash the aeroplane! You must fly the wheels smoothly onto the runway FIRST, before easing the stick forward a little. Finesse, it takes finesse.

Some tail draggers should always be 'wheeled' onto the runway because they should not be 'three pointed'! These are usually older style tail draggers whose three point attitude is the same as its level stall attitude and that have 'dodgy' stall characteristics. These dodgy stall characteristics are usually associated with highly tapered wings, causing tip stalling. Probably the best known example of this type of tail dragger is the venerable old Douglas DC-3 airliner. You will never see one of these aeroplanes 'three pointed' as a wing drop just prior to touchdown could be catastrophic in a 'Gooney Bird'.

Wheeling a 'Gooney'

Conversely, I always three point my Pitts even in the strongest of crosswinds, because it has the controllability to allow it and because the un-damped rubber undercarriage bungees love to be given a chance to bounce me back into the air if I misjudge a wheeler. Other models of the Pitts range with spring steel undercarriage struts and other similar aeroplane types give the aviator the option.

In the 'good ol' days' when tail draggers were the norm, all over grass airfields were also the norm, so the aeroplane could always be landed into the wind. Nowadays narrow sealed runways virtually guarantee a crosswind, so if you are going to fly a tail dragger being adept at wheeler landings is a necessity.

Annex C

Keeping straight in a Tail Dragger

As mentioned in the main text of this lesson, keeping straight during the roll out in a tail dragger can be a challenge. This is because the aeroplane is directionally unstable and direct forward visibility is often non-existent. To control these unstable characteristics, the aviator must learn to ‘tap dance’ on the rudder pedals to keep it rolling dead straight, but where to look to get the correct information to do this?

Keeping straight in a tri-gear aeroplane is comparatively simple; you focus on the centerline some distance ahead of the aeroplane and your visual balance mechanism provides you with the cues which enable you to correct any deviations before they become excessive. We do the same in a tail dragger!!

Huh! How can this be when our forward field of view is full of engine cowling and we don’t have ‘x-ray vision’?

To explain I must digress for a few moments into some simple human physiology, particularly that of the eyeball and the balance/orientation mechanism. Eighty percent of the information the brain requires to balance and orientate itself (and you) comes from the eyes. The eyeball is an amazing device which enables us to see things, but all things are not seen equally clearly. Focus, really focus, on a letter, any letter, in the middle of this page; it’s really clear isn’t it? Now without changing your point of focus, be aware of how many letters you can see clearly either side of the focus letter. Not many stay in focus do they? Maybe one or two on each side only. This is because the ‘focal vision’ of our eyeball subtends a cone of only about one degree whilst the remainder of the 150º of our field of view is our ‘peripheral vision’. So what!?

The focal vision cone defines to the brain where we want to go but the peripheral vision provides the orientation data which enables us to go there. (This is why my daughter kept going to the tree when she looked at it, because her brain thought it was the goal.) So in a tail dragger, if we look off to one side of the nose the brain will take that as the objective and we will go there!

Try this simple exercise. Look out of the window at a distant point; now hold your finger up at arms length near to where you are focused. Now move your finger from side to side….what do you see? Only a finger moving. Now focus on your finger and once again move it from side to side. Now you will be aware of everything in your field of view moving, even objects way outside your point of focus. It is the awareness of the movement of your entire field of view which is the data the peripheral vision sends to the brain, thereby enabling it to correct for directional deviations.

So during the roll out after a three point touchdown in a tail dragger, focus on a point on the engine cowling straight ahead of you and use the information streaming into your brain through your peripheral vision to keep straight. Initially this will feel strange, because we are usually able to focus on where we wish to go at all other times in our life, so breaking out of this ‘habit’ takes some concentration, but trust me it works.

When I was instructing landing technique in my Pitts S2A I would tap the back of my head during the roll out to emphasize that that is where the student should be focused. (The instructor sits in the front seat in a Pitts.) Now this technique not only works during the roll out but is also the best way of determining the flare and the hold off too. After all, once the flare is started the engine cowling starts to get in the way so where else are you going to look?

Even though it was possible to drop the cockpit side panels of a Tiger Moth and lean out a little, thereby getting a better view of the approach, as soon as I commenced the flare I would sit up straight and use my peripheral vision for the landing, it never failed me. However, I have watched other Tiger Moths run off the runway whilst the pilot craned his head out the side to see where he was going during the roll out. They all ran off on the same side as the pilots head was protruding.

Maintain your straight-ahead focus on the engine cowling and tap dance on the pedals until the aeroplane has slowed to taxi speed, and then you may look for the runway exit and taxi off the runway, being aware of all of those things I am about to discuss in Annex D.

Annex D

Taxiing a Tail Dragger on a Windy Day

Because of the unstable undercarriage configuration of a Tail Dragger the tendency for it to swing into the prevailing wind is always present. However, additional care must be exercised over where the control stick is positioned when taxiing in moderate or strong winds because directional control can be even more easily lost, or worse, the aeroplane can be 'parked' on its nose!

Let's talk about the latter, more spectacular possibility first. Imagine that you have just performed a perfect crosswind landing in a crosswind from your left. You have pinned the tail wheel with full back stick and have moved the aileron control to the left during the rollout. Now at taxi speed, you turn off the runway onto the taxiway on your right whilst keeping the stick fully back and over to the left, but now that you have turned through 90º your control position is all wrong for the relative wind direction you will now be experiencing.

The crosswind has now become a tail wind and this tail wind may be stronger than the slipstream from the idling propeller, resulting in airflow over the tail from the rear, which, because of the elevator angle, can lift the tail off the ground and stand the aeroplane on its nose! Surely that would take a lot of force you may think. No, a tail dragger can be quite light at the tail. When I was 16 and worked as a tarmac hand at the local aero club I would regularly move Tiger Moths around by picking up the tail, placing the rear end of the fuselage on my shoulder and 'walking' the aeroplane to where I wanted to position it. I have also moved my Pitts around in a similar fashion. The point is not how strong I was, but how little wind is needed to pick up the tail and flip the aeroplane onto its nose. A few years ago I watched in horror as the pilot of a Pitts Special achieved this exactly as I have just described. See Figure One.

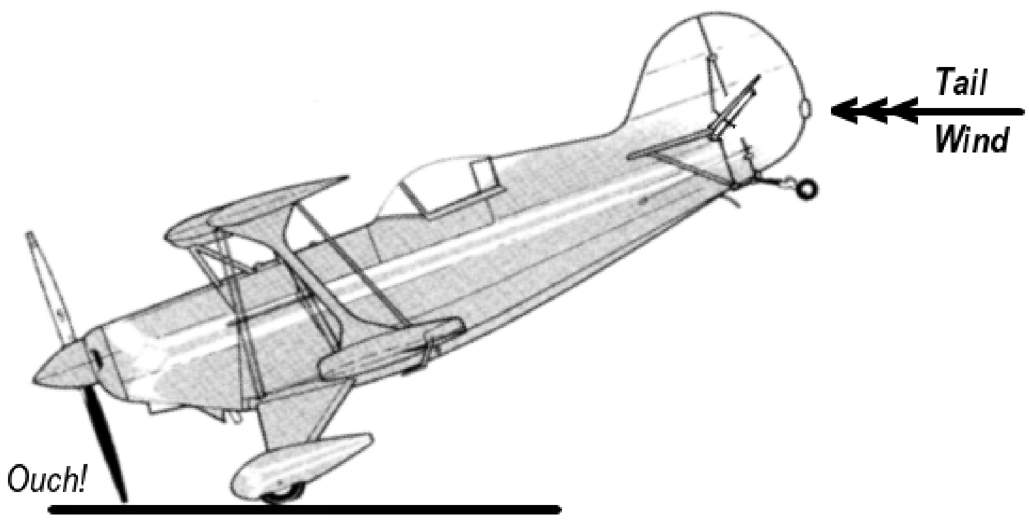


Figure One

So what is the counter for this? Obviously don't have the stick fully back when taxiing with a tail wind. But how far forward should we move it? Just enough to set the elevator parallel to the ground. This means that the tail wind will encounter the elevator at zero angle of attack but the stabilizer at a negative angle of attack, thereby providing a downward force to pin the tail down. See Figure Two.

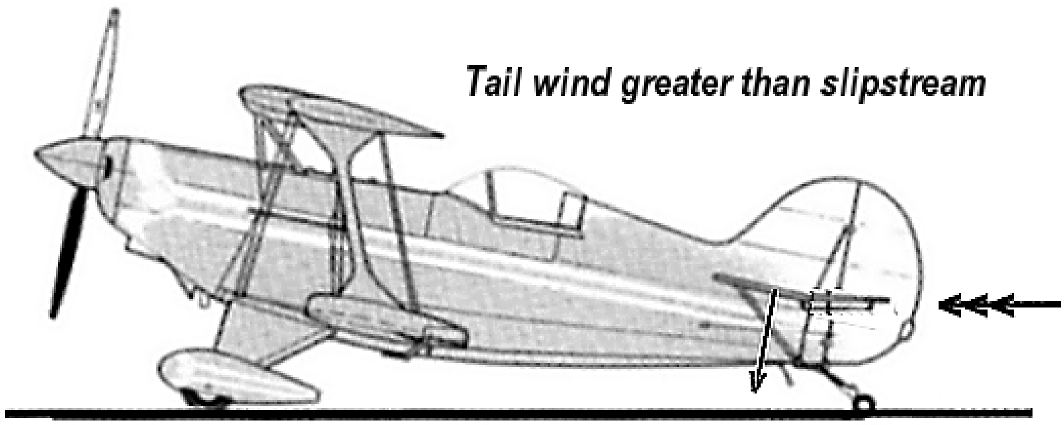


Figure Two

If you increase power such that the slipstream is greater than the tail wind then the slipstream will encounter the stabilizer at zero angle of attack and the elevator at negative angle of attack, once again producing a downward force to pin the tail down. See Figure Three.

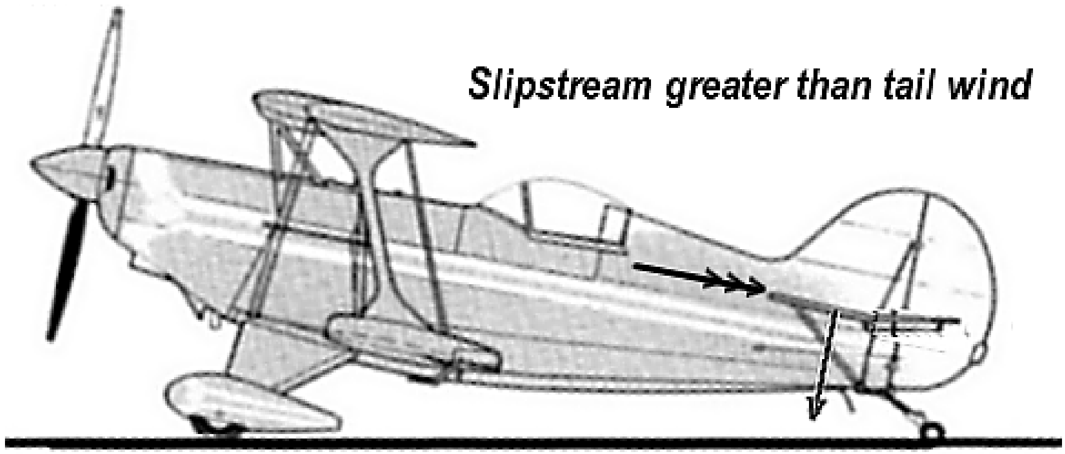


Figure Three

Before you taxi anywhere, sit in the cockpit, look over your shoulder at the elevators and determine where to put the stick to position the elevators parallel to the ground. You will find that it will be approximately half way between neutral and fully back.

What about the aileron control? Directional control difficulties can be encountered in a tail dragger if the 'into-wind' wing is lifted too much by the prevailing wind. Remember the wings are at or near their maximum lift angle of attack when on the ground, and are therefore more susceptible to wind effects while taxiing, especially if they have any dihedral or sweep back (like a Pitts or Tiger Moth). Obviously the pilot should move the aileron control to offset the wind effect as much as possible, but which way to move it?

When taxiing with the wind coming from anywhere within the front 180º the stick should be moved 'into' the wind, but when taxiing with the wind coming from anywhere within the rear 180º, the stick should be moved 'down wind'! Huh! When taxiing with the wind coming from the rear hemisphere it will be flowing over the ailerons in reverse and, just like the elevators in the previous example, will tend to lift them if they are held 'stick into wind'.

So putting this all together: when taxiing with the relative wind coming from anywhere *ahead* of abeam….stick back and into the cross wind. When taxiing with the relative wind coming from anywhere *behind* abeam….stick only *half* back and *downwind*. See Figure Four.

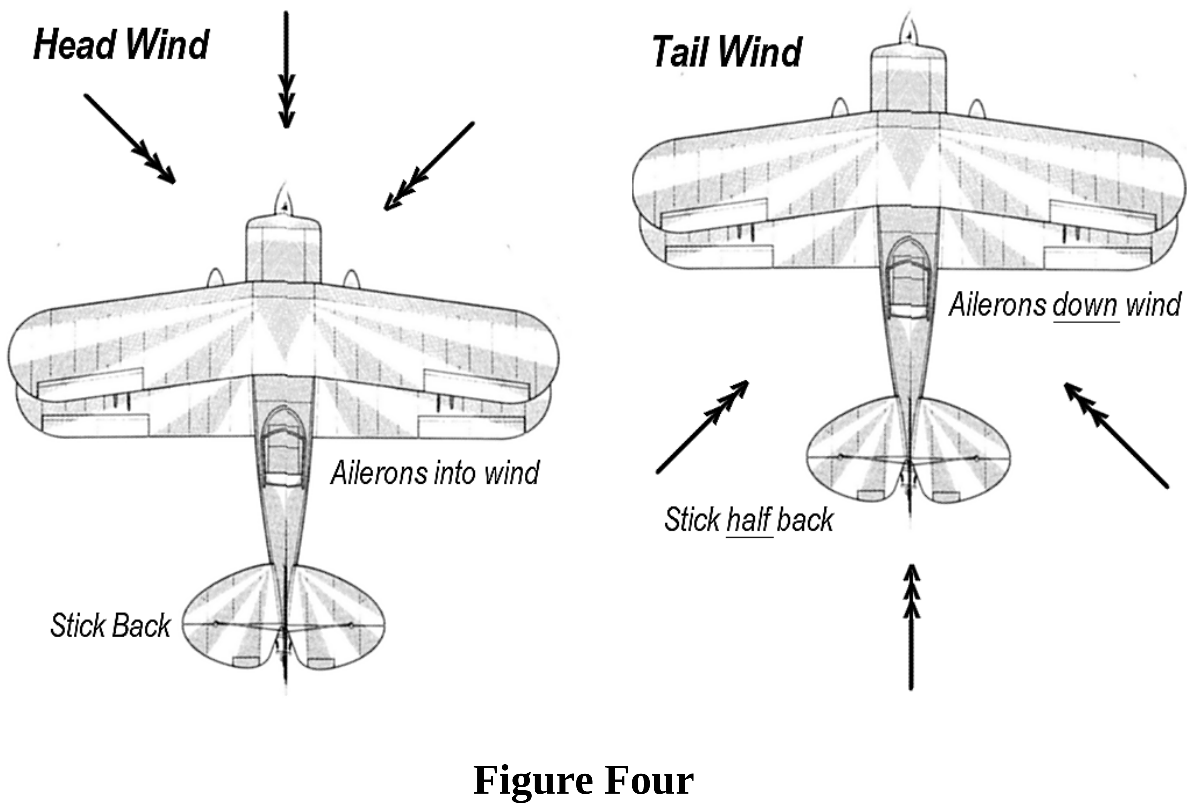


Figure Four

There is an old adage that says, "The landing ain't over till the chocks are in place". This applies especially to tail draggers. From the time the aeroplane has decelerated to taxi speed at the end of the landing roll, the pilot must be alert to the direction of the relative wind and position the controls accordingly. This will mean moving the stick around the cockpit quite often as the aeroplane follows the taxi route back to the parking area. Keep thinking "where is the relative wind coming from now" each time you turn, and don't relax your concentration for a minute.

Lesson Four

Short Field Landing

Why do we need to learn a short field landing technique? Obviously we need it when the runway we are landing on is too short for a normal landing! But how often is this likely?..... Rarely.

The simple fact is that, as a private pilot, you will rarely need to land at an airfield which is so short as to require this technique. You may argue that the 'crash comics' published by the various regulating authorities are usually full of stories about aeroplanes that have 'over-run' the runway on landing. True, but if you read the reasons given you will note that their pilots were not even making a reasonable 'normal' approach and landing. They were usually too high or too fast (or both) or landing 'downwind' (!), and elected to try to 'rescue' a botched up approach and not go around; touching down so far down the runway that there was insufficient distance remaining in which to stop!

There is an old aviation adage which says: "the runway behind you is as useless as the altitude above you and the air in your tanks!"

A well executed 'normal' landing will be sufficient on 99% of all airfields you will choose to land on. Think of it this way; most short strips are usually situated on someone's private property, and this someone is probably a private pilot with an aeroplane of similar performance to yours and no more talent than you. So the owner is not going to risk his or her neck, or aeroplane, by deliberately making the strip unnecessarily short. Occasionally you will come across a really short strip and it will be obvious why it is not longer. There will be an obstacle in the way, like a hill or a creek or a stand of trees. If you choose to land on such a strip you will need this short landing technique. Of course you can always choose the option of not landing there too.

I must also emphasize that a modern light touring aeroplane is not a purpose built STOL aeroplane (Short Take Off and Landing); therefore it cannot be safely landed much shorter than it could using a good normal landing technique, and it cannot approach much steeper either. I am often bemused by young flying instructors who demonstrate their short landing technique by approaching very slow and very flat and attempt to put their wheels on the very edge of a normal length runway to impress their students. If the terrain approaching a real short field allowed that, it would contain more runway and wouldn't be a short field anymore! Short fields are short because there are obstacles which should be avoided. These same obstacles can also cause turbulence and wind sheer, so aiming to touchdown on the very end of the runway and not allowing for the possibility of last minute 'sink' is inviting disaster.

I have spent some time as a check and training captain in Papua New Guinea flying DeHavilland Caribou aircraft for the Royal Australian Air Force. The Caribou is a purpose built STOL aeroplane which weighs 28,500lb and has a 98ft wingspan with full span double slotted 80º Flaps and reverse thrust. It can land in the same space as a Cessna 172. Now, PNG contains many airstrips which were still challenging for this aeroplane (see the photo at the end of this lesson), and the terrain never allowed Caribou pilots to make a flat approach to any of them. Also, if any pilot developed the bad habit of aiming at the very end of the strip and not allowing for a possible undershoot he was subject to many sessions of 'retraining', usually back home in Australia.

Did I say I was bemused by flying instructors who teach such appallingly bad techniques? Try angered! They are giving the wrong message to their students.

So one day you may be flying a normal aeroplane into a short strip via a normal approach angle. All you can do is reduce the kinetic energy that the aeroplane will have at the keyhole a little, thereby reducing the hold off distance and giving those little brakes a better chance of dissipating the remaining energy within the remaining runway after touchdown. How do you do that?

First let me answer the obvious question; "how much can we safely reduce the kinetic energy at the keyhole?" Which can be translated into "how slow can we safely be at the keyhole?" The answer is 1.2Vs. The difference between the normal threshold speed of 1.3Vs and the short landing threshold speed of 1.2Vs for most light aeroplanes is only about 5 knots. This 5 knot difference contains the kinetic energy we would normally dissipate during the hold off, so if we can dissipate it before we reach the keyhole we will eliminate the 'float' down the runway during the hold off, and touch down quite close to our initial aim point (which should NOT be the very end of the runway!). To avoid arriving like a bag of wheat we need to adopt a technique which will still provide a 'non-wheat bag' landing, so let's discuss this technique.

First, we set up a normal approach as detailed in Lesson Two. If we have assessed the wind correctly we will stabilize the approach with either the primary ARP or a 'dot' below it (adjusted ARP) on the aim point. Yes, we will be using the same 150 meter aim point too. When at double the distance we normally use as a slowdown point, that is, at about 400 meters from the threshold, select full flap and allow the aeroplane to slow. Continue holding the ARP on the aim point. The aircraft will slow to its normal threshold speed by the time it reaches 200 meters from the end of the runway, and then will continue slowing down. This is where the slow speed technique 'kicks in'. If, once the speed slows below the normal threshold speed, we don't make a progressive attitude correction the aeroplane will start to 'sink' short. To prevent this 'sink', the nose must be raised at such a rate that the aeroplane continues toward the aim point. The ARP will of course no longer be indicating where the aeroplane is going, but it will be only one or two 'dots' higher than normal. Also you will be able to assess where the aeroplane is going even without the ARP because you are now only about 200 meters from the aim point (and you will have become proficient at 'normal' landings prior to this training).

At about 100 meters the speed will have reduced to 1.2Vs and the aeroplane will be in about the cruise speed level flight attitude and sinking toward the aim point. (Figure One.) Because the aeroplane is now on the 'backside' of the drag curve it may be necessary to momentarily increase power a little to maintain this speed.

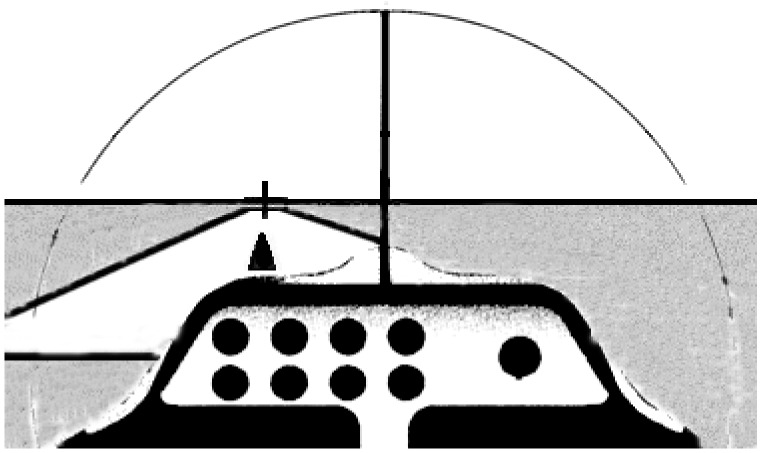


Figure One – 100 Meters at 1.2Vs

As the aeroplane enters ground effect at the keyhole, smoothly close the throttle to idle power and simultaneously raise the nose to the normal landing attitude and hold it there (Figure Two).

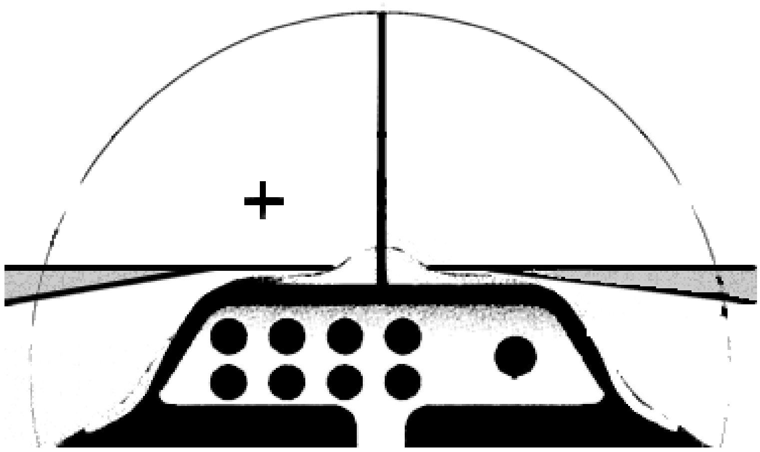


Figure Two - Touchdown.

The aeroplane will perform a 'half flare' without fully leveling off and quickly settle to the ground. The main wheels will make contact with the runway at or just past, the aim point. (Figure Three.)

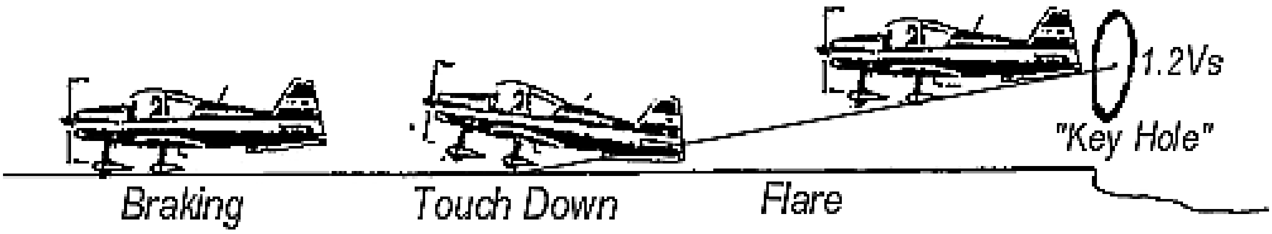


Figure Three

The touchdown will be with a slight ‘bump’ as the wheels make contact but this is to be expected. Hold the stick till the nose wheel lands, which it will do quite quickly, and then pull it all the way back as you apply the brakes. Use the brakes judiciously because you will probably be landing on grass, and it is easy to lock the brakes and slide on grass, which of course will destroy the braking efficiency and undo all of the good work you have done to achieve a good short field touchdown in the first place. With the stick held hard back you will achieve two things during the roll out. The first is to increase the load on the main wheels (just like the ‘spoiler’ on the back of a race car) and the second is to reduce the load on the nose wheel strut and help keep the propeller clear of the ground.

As mentioned in the previous lesson, some tail dragger pilots will raise the landing attitude a little above normal when making a short field landing so that the tail wheel lands first, causing the aeroplane to pitch forward onto the main wheels and thereby rapidly reducing the angle of attack and ensuring the aeroplane “sticks”. (Figure Four.)

Figure Four. Tailwheel *slightly* below main wheels

Annex A to Lesson Three discussed when to close the throttle when making a normal landing. Many of the considerations discussed apply to the short field technique too. For instance, closing the throttle at the keyhole works for a low wing aeroplane but may result in a ‘too positive’ touchdown in a high wing aeroplane, so delaying the throttle retardation a little or retarding it just a little more slowly should smooth things out a bit for a high wing aeroplane. If you are flying a low inertia aeroplane, closing the throttle just before the wheels touch is probably the best technique. I must add that I have never encountered a field so short as to require this technique in a low inertia aeroplane…I have landed an ultralight on a cricket pitch using normal landing technique!

Now a note of caution. If you have misjudged the approach and have closed the throttle fully in order to slow to 1.2Vs at the keyhole, you may be developing such a high sink rate that just setting the landing attitude will not prevent a ‘bag of wheat arrival’! If you feel this happening in the last 10ft or so, (and you *will* feel it) hold the attitude and give a short burst of power and accept touching down a few meters past where you had expected. There is no point damaging the aeroplane to save a few meters of roll out - indeed if the field is so short that you feel required to accept this possibility, what the hell are you doing attempting a landing there in the first place!?

You may also find that the wind and the approach area obstacles produce a downdraft or wind sheer that cause your aeroplane to suddenly sink short of your aim point as you pass through the keyhole! If you have aimed 150 meters ‘in’ you will at least touch down on the runway, but you will also need to give a short burst of power to avoid being a wheat bag.

I want to reiterate what I said in Book One - Lesson Twelve, regarding threshold speeds and runway length when a ‘crosswind’ prevails. Crosswinds are normally associated with headwinds, so in such a wind it may not be necessary to adopt short field technique at all. However, if the field is so short that it demands the slowest safe threshold speed but the crosswind is so strong that it demands an increased threshold speed, then that is the day you go and land somewhere else. Of course any headwind means that the aeroplane’s ground speed at the keyhole is less, and therefore its kinetic energy relative to the ground is less, so it may not be necessary to adopt the technique I have just talked about at all!

Finally, let me emphasize that a good short field landing requires <u>all</u> of your attention. Do not allow passengers or the radio to break your concentration during this crucial stage of flight, or this could happen to you: (Figure Five.)

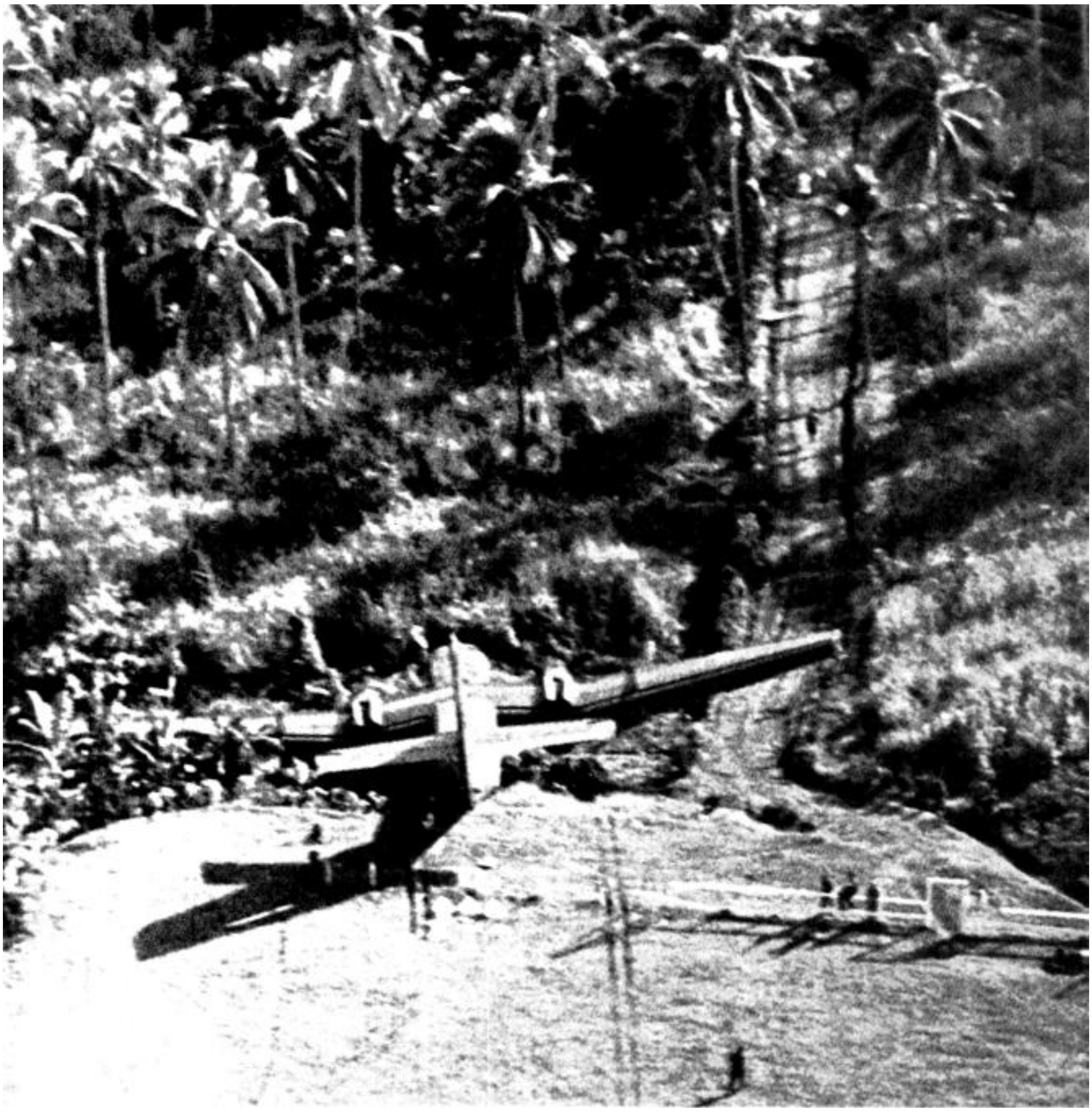


Figure Five

The result of my Caribou instructor's demonstration of how not to land on short 'one way' airstrips in Papua New Guinea, whilst talking on the radio! (April 1971)

Lesson Five

Glide Circuit

In Book One - Lesson Nine, Gliding, I opened with the statement: “Gliding is a sport enjoyed by hundreds of thousands of aviators world wide. It is usually done in purpose built ‘sailplanes’. For the rest of us, gliding is usually done in the event of a power failure or practicing for the inevitable power failure”. (Yes, I said inevitable!...If you have decided on a flying career it **will** happen to you!)

In this lesson I wish to describe my technique for converting a theoretical knowledge about gliding into a practical and easily executed procedure for judging and flying a glide approach to a chosen landing site, thereby giving you and your passengers the best chance of surviving that inevitable engine failure. In this lesson I am going to discuss just the final glide circuit from a point abeam the chosen touch down point as this is the most critical part of any ‘engine out’ forced landing procedure. I will discuss how to select and reach this point in the next lesson.

I have found, over the years, that many pilots avoid practicing glide circuits because they don’t fit into the ‘traffic pattern’ at their local airfield, or they are embarrassed when they misjudge them and ‘die’. These pilots develop the ostrich approach of putting their head in the sand and hoping an engine failure won’t happen to them!

I am also bemused when I hear of flight schools which teach a type of glide circuit at their home airport which is designed to fit into the local traffic pattern and which differs from what they teach as part of their forced landing training. Why should there be a difference? A glide circuit in a modern aeroplane has no application other than pilot practice for an engine out situation. If the forced landing glide circuit is not compatible with the local airport traffic, go find a satellite field where you can practice without interruption. My technique is incompatible with normal airport circuit procedure, so you are going to have to find somewhere other than your local field if you choose to practice it, unless of course, you are based at a quiet airfield that can accommodate it.

Nowadays the pilots of modern aeroplanes are taught to make a power assisted approach and vary their approach path with attitude and power adjustments, so even ‘compatible’ glide approaches are not practiced very much. But how near the ‘real thing’ is this practice anyway? Consider this: an aeroplane engine idling on the ground is turning at approximately 600 RPM and at gliding speed about 1000 RPM, (I refer you back to Book One - Lesson Four, Thrust, for the reason for this) so in a simulated ‘engine out’ glide the propeller is delivering some thrust, or at least not creating drag. This will improve the aeroplanes glide performance by 5-10%! The reverse applies in a real engine failure as the engine is now being driven by a ‘wind-milling’ propeller and as a result its drag, and therefore the total drag, has increased significantly. This is something which cannot be simulated with safety but does have a marked influence on the aeroplane’s ‘real’ glide performance. (This wind-milling propeller drag is the primary reason that multi-engine aeroplanes have feathering props.)

The final landing which results from an engine failure is rarely performed off a ‘straight in’ approach from the point of failure. Indeed it would be foolish to attempt one (given a choice) as there are fewer options available to the pilot to ensure a safe outcome. All flight schools teach some form of pattern which should be flown around the intended landing site to give the pilots maximum flexibility in their judgment. This pattern involves turning the aeroplane several times and, as we saw in the lesson on manoeuvring (Book One), this involves an increase in lift induced drag. To reiterate, an aircraft in a 45^{o} banked turn requires 1.4 times more lift from the wings than it did in straight flight. This means that in each turn the angle of attack of the wings has to be increased to 1.4 times that required for straight flight, which means that the induced drag doubles! ($1.4^2 = 2.0$). Now if you remember my ‘rule of thumb’, the total drag has increased by a factor of 1.4 too. So, turning the aeroplane causes the minimum drag speed to increase, which of course means that the ‘best glide speed’ increases too! Also, as we saw in that lesson, the turn rate and radius may also be a factor which determines the bank angle we must use.

So what is the ‘best glide speed’ at any point in this glide circuit? Well it is obviously going to be different to the one declared in the aeroplane’s ‘Flight Manual’, but who knows exactly!?

Let me now talk a little about the philosophy of forced landing procedures. At bottom line, what is the purpose of a forced landing procedure? The primary objective (really, the **only** objective) is to give the occupants of the aeroplane the best possible chance of walking away from the situation unscathed. Everything else is secondary; **everything**. If the aeroplane survives intact, that is a bonus, but attempting to ‘pull that off’ as well, should in no way degrade your chances of achieving the primary objective.

Consider the common ‘teaching’ of using the published ‘best glide range speed’ to fly the whole pattern including the final approach. Suppose that when at 200ft the aircraft starts to ‘sink’ short of the chosen field! Raising the nose attitude at this speed will not help; indeed it will make the situation worse. Using best glide speed means it doesn’t get any better - there is nothing in reserve! (It is like planning a cross country flight to the last drop of fuel and then running out of ‘gas’ one mile short of your destination! You just wouldn’t do it....would you?) Having an extra 10 or 15 knots of airspeed on final approach will give the aeroplane a reserve of energy to compensate for unexpected ‘sink’ and potential undershoot (it will also allow you to ‘penetrate’ into the headwind you should be landing into). So now, if the aeroplane does start to undershoot, the nose attitude can be raised a little to convert this extra energy into distance, and the aeroplane can ‘make it’ to the field.

We can sit back in our chairs at home and pontificate and say “well the pilot should have judged the approach better”. Well, yes he should, but he didn’t. Do he and his family (let’s assume they are on board too) deserve to die because of a slight misjudgment whilst under stress, which allowed the aeroplane to sink short into the trees and break up? I don’t think so! “But” you might argue, “what if there is no sink? Now the aeroplane will arrive at the touchdown point 15 knots ‘hot’ and float, perhaps running into the trees at the far end of the field”. Good point, but the proper use of sideslip can wash off much of this excess speed right up to the point of touchdown, and ‘dumping’ the flaps at this point will eliminate the tendency to float. Once on the ground, the use of maximum braking should dissipate the rest, but if it still looks like it won’t stop within the remaining distance, just take the foot off one of the brakes! This will cause an immediate ‘ground loop’ (even in a ‘tri-gear’ aeroplane), which will dissipate the remaining energy. It may also collapse the undercarriage, but the aeroplane will only continue another 20 meters or so before it comes to rest in a cloud of dust, damaged but right way up and essentially intact, allowing the occupants to dismount unscathed.......primary (**only**) objective achieved.

So what is the ‘best glide speed’? It is the speed which gives the occupants of the aeroplane the best chance of surviving an engine failure unscathed.

I have sat in the right seat with licenced pilots (not trained by me) whilst they have flown a glide circuit as part of a simulated forced landing procedure, gliding at the published ‘best’ glide speed, and have watched them accept a gross overshoot situation when gliding down final approach rather than lowering the attitude to attain their chosen touchdown point. What were they thinking of? Where were their priorities? If lowering the attitude causes the full flap (which should be extended by now) limit speed to be exceeded, so what! Arrive at 85 or even 95 knots if necessary, use maximum sideslip, ‘dump’ the flap as you flare and continue with the braking technique I have just mentioned. (In all of these cases the student had not been trained in the ‘art’ of side slipping either!)

There is a golden rule which states that: “The chances of survival vary inversely with the angle of impact!” Therefore if you ‘arrive’ under control at a tangent to a flat surface your chances of survival are good, but fly into trees or stall and flip to a vertical impact with the ground and your chances are zero!

So what is the best glide speed? Whatever works to ensure that you and your family live through the experience!

Okay, so how do I teach my students to fly a glide circuit? My procedure involves a constantly turning approach centered on the chosen touchdown point until a straight final approach path is intercepted. Let me expand on that.

Imagine you have a plastic funnel, the sort you use to fill narrow neck bottles with, and imagine you roll a small ball (like a ball bearing) around the inside rim of the funnel. Gravity will pull the ball toward the hole at the bottom of the funnel whilst the momentum of the ball causes it to roll around the inside in a circle. The resulting path that the ball takes will be a spiral of decreasing radius (a conical spiral), as it descends toward the hole at the bottom, see Figure One.

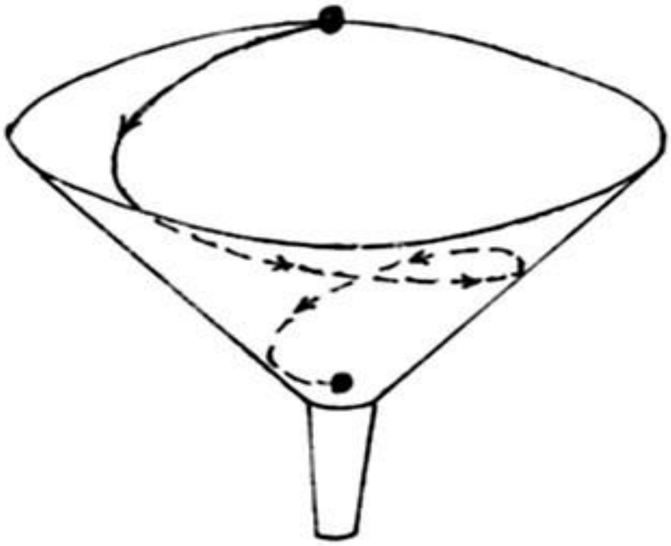


Figure One

When viewed from above, the path the ball follows looks like this. Figure Two.

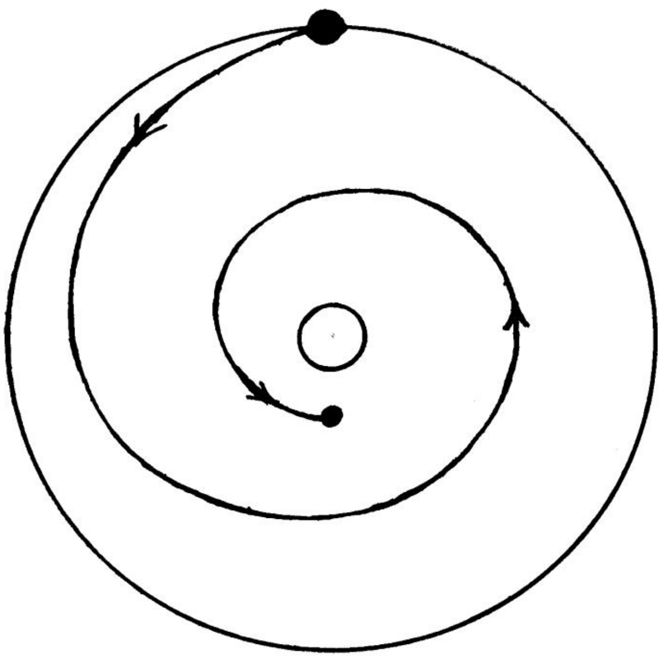


Figure Two

If you were riding along on the ball and you looked down toward the hole, you would note that it was always at the same angle down from horizontal regardless of how far down the inside face of the funnel you had traveled. This is an important point so I will reiterate. As the ball descends it gets closer to the hole such that at any point on this conical spiral path the angle down to the hole is the same as at any other point and is, of course, the angle of the cone of the funnel. This is depicted by the radial arrows in Figure Three.

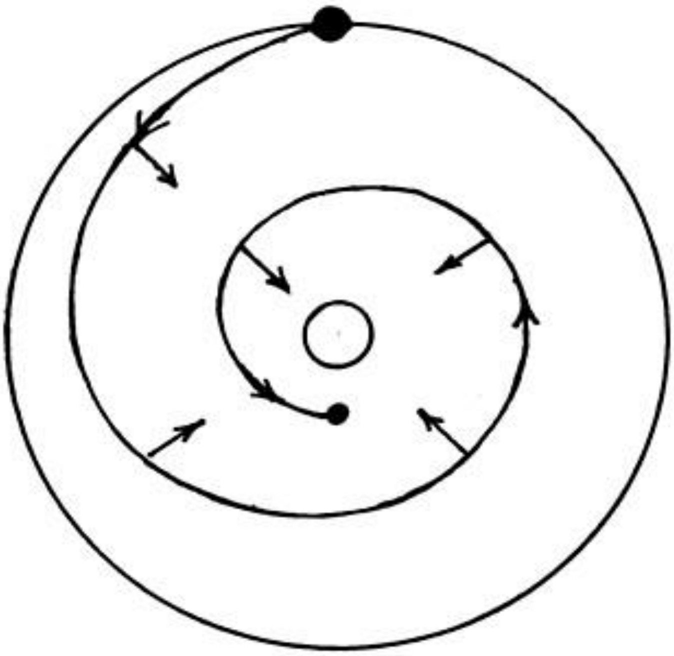


Figure Three

Now imagine that the ball is a gliding aeroplane, and the angle of the funnel wall is steeper than the aeroplane's glide angle. As the aeroplane descends it will follow a similar path to the ball, and if at any point on the spiral it were to turn and point directly at the hole, it would be flying down a steeper approach path than its optimum glide angle, thereby virtually guaranteeing that it would 'make it' to the hole. Indeed it would make it to the hole somewhat faster than glide speed, necessitating some form of braking to control its speed.

Finally let's imagine that the hole at the bottom of the funnel is a chosen aim point on a suitable landing field and that the path straight down the inside of the funnel is the final approach to land. The point at which to turn onto this final landing approach will of course be defined by the orientation of the chosen landing path (runway). See Figure Four

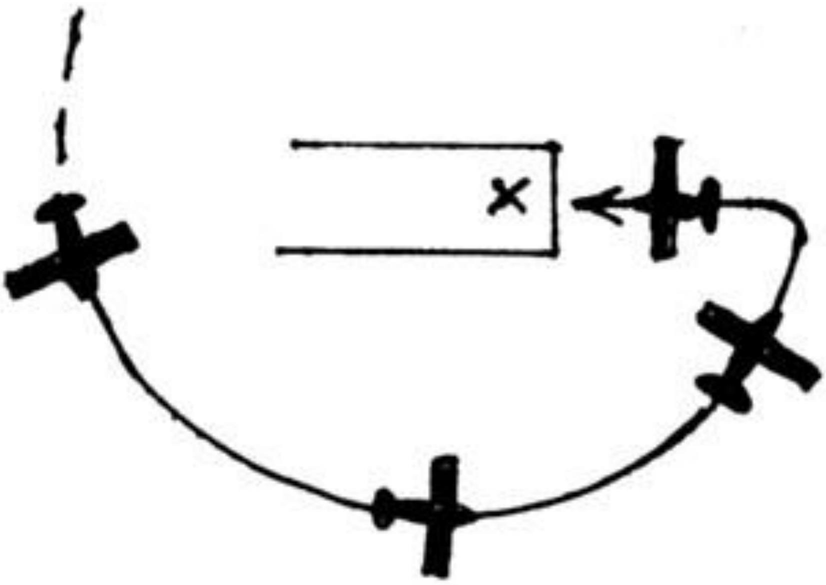


Figure Four

So we fly our aeroplane around the aim point, holding it at a constant angle until we can intercept the final approach path aligned with the 'runway'. Once we have turned the aeroplane onto final approach we aim it at the aim point (using the ARP) and control the speed with sideslip and flap.

How do we determine the angle to the aim point whilst circling the field (the angle of the funnel)? This will depend upon the aeroplane to a degree; however most light training aeroplanes have similar glide angles. You will have to experiment with this a little but this is how I set it up on my aeroplanes. I use one of the rib lines defined by a line of rivets on the wing to define the 'funnel angle' when the wings are level as shown in Figure Five.

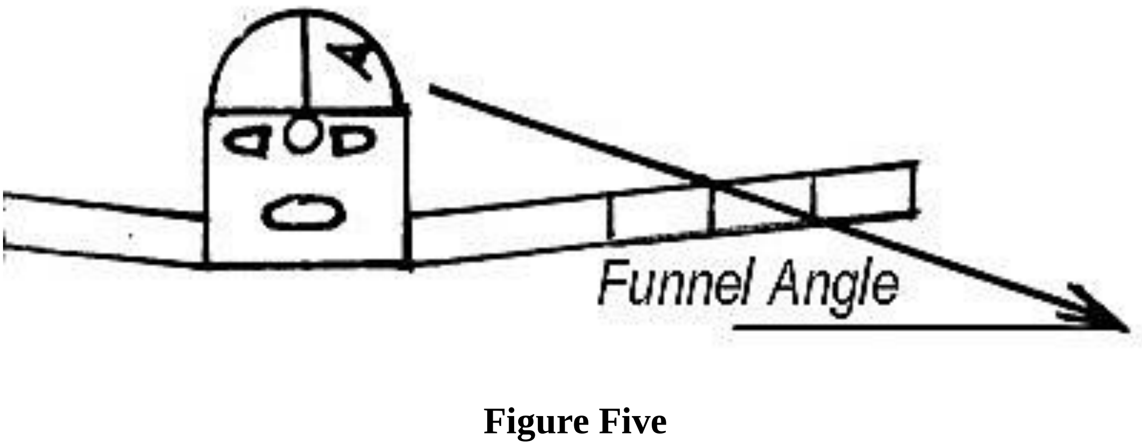


Figure Five

Figure Six is the same angle as viewed from the cockpit. Note that the angle looking down at the wing reference point is the same as the angle to the aim point.

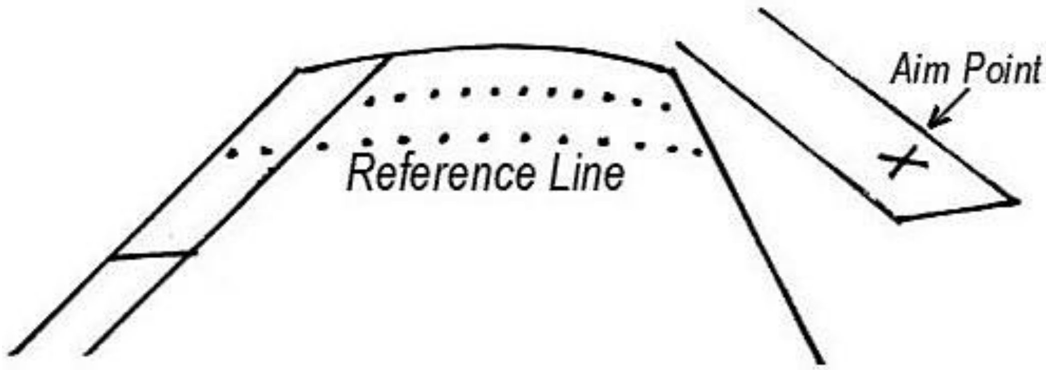


Figure Six

As each of the aeroplanes in my fleet became due for the inevitable repaint, I redesigned the paint scheme to define this rib line with two stripes as shown in Figure Seven in order to make it easier for my student pilots to determine the correct angle.

Figure Seven

What if you are training on a high wing aeroplane? Well to the best of my knowledge all high wing training aeroplanes have wing struts, so marking a line on each strut at the appropriate place will do the trick, (use the ARP white board marker). I once operated a Cessna 152 Aerobat for a while and I permanently marked the angle with electrical tape on each strut. See Figure Eight.

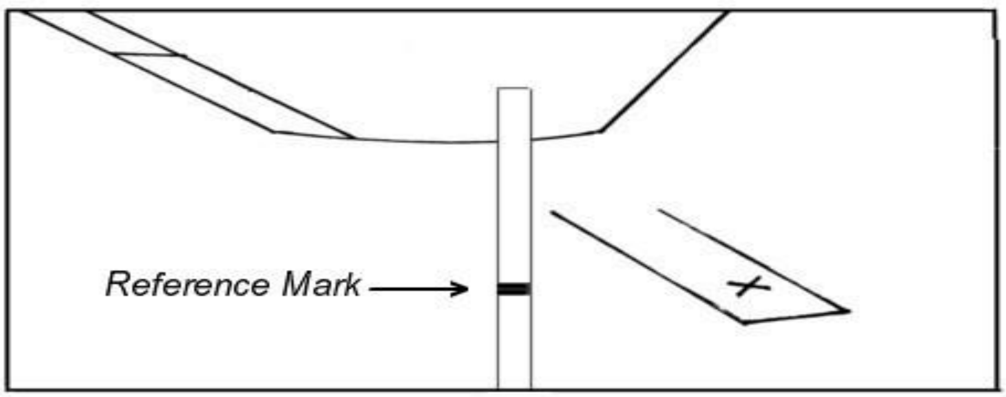


Figure Eight

The question has obviously popped into your mind at this point: how can this mark, set up wings level, be any of use when the aeroplane is banked in a turn? Good question. The radius of the turn is such that only a small bank angle is required to fly the curve, so in order to use this angle reference line, it is better to make a series of small turns through about 15º to 20º heading change and then returning to wings level to check the angle. This has the advantage of positioning the aim point just ahead of the leading edge of the wing (on low wing aeroplanes) so that the angle can be assessed before the aeroplane's forward motion causes it to move back and be obscured by the wing. (It will also move out because we are descending.) So the actual flight path, viewed from above, looks like that in Figure Nine. (Of course this 'problem' of keeping the aim point in sight is not a problem in a high wing aeroplane, but you will still have to level the wings to check the angle.)

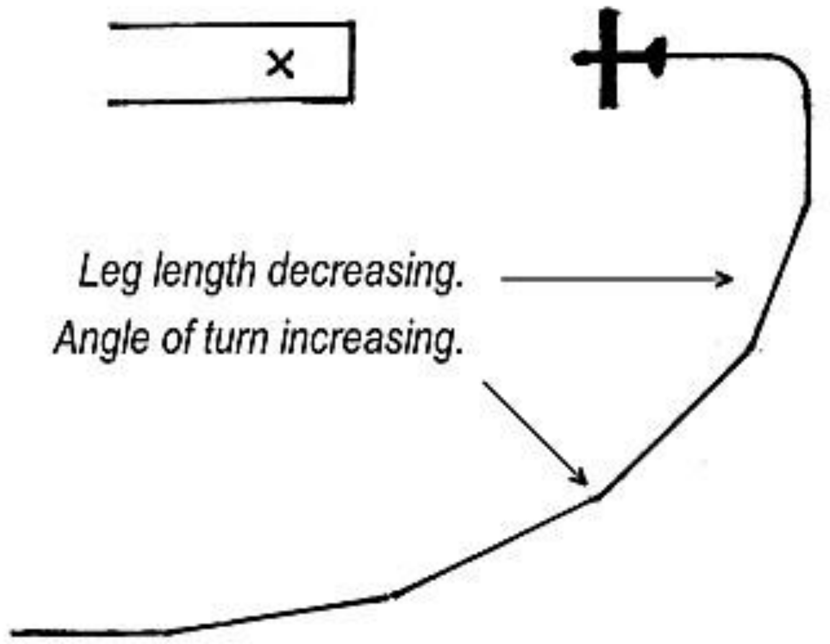


Figure Nine

Note that as the aeroplane descends deeper into the funnel the individual 'legs' become shorter and the angle through which the aeroplane should be turned increases because the radius of the funnel is decreasing.

In the last part of the funnel, from the position abeam the aim point to the point where the final approach is intercepted, any 'wind' will require the aeroplane to be angled toward the airfield to stay on the funnel; this will automatically compensate for drift and will make the aim point visible ahead of the leading edge at all times, as shown in Figure Ten.

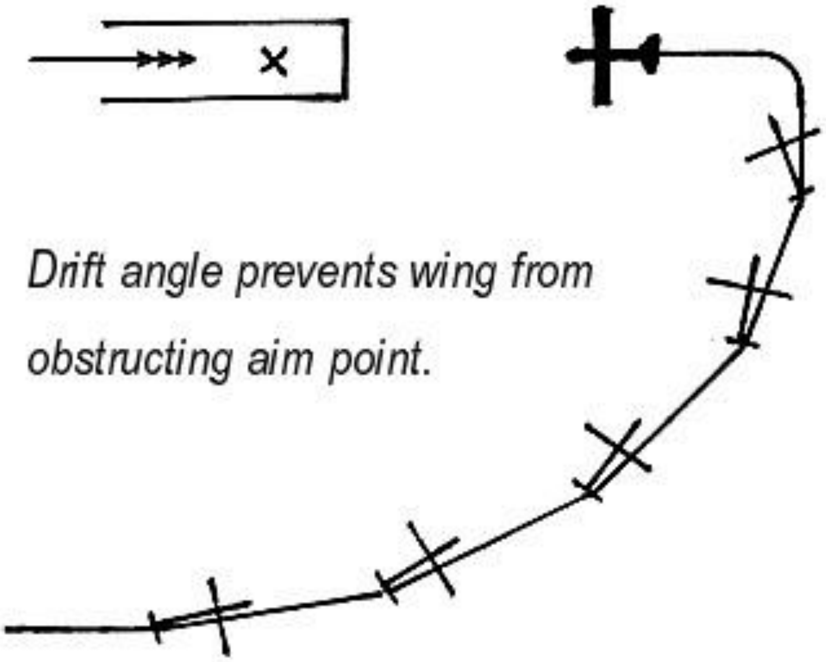


Figure Ten

Okay, so now we can determine whether or not the aeroplane is positioned on the funnel, but what do we do if it is not? If the aim point appears outside of the reference line when we level the wings we are obviously too wide and at too flat an angle, so the next turn must be more positive to move closer. Conversely, if the aim point appears inside the reference line we are too close and at too steep an angle, so we either have to turn away a little or delay the next turn toward until, due to the fact that we are descending, the aim point moves out to its correct position. (If we are very close we may have to hold heading until the aim point appears behind the trailing edge of the wing.) Figure Eleven shows these two situations.

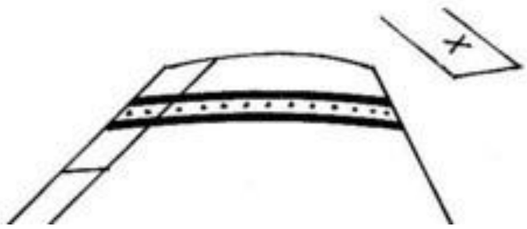


Figure Eleven (A) Outside, too wide. **Figure Eleven (B) Inside, too close.**

I now refer back to the opening paragraphs of this lesson where I mentioned that a windmilling propeller is going to cause a steeper glide angle than can be safety simulated. This will simply appear as a tendency to fly wide on the funnel and can be easily corrected by turning in more positively. In this way this 'funnel technique' automatically compensates for differences in glide angle. I will return to this point again in a moment.

It is now time to discuss another factor, and that is our height above the chosen landing field. First, if the field is not at sea level your altimeter is not going to give you a true indication of your height above the field; indeed you may be unaware of the exact height of the terrain over which you are passing when you do suffer an engine failure, and valuable time can be lost trying to figure it out. Second, the altitude that you will be flying will, most probably, not allow sufficient height above terrain to allow you to fly a prolonged spiral descent as depicted in Figure Two. So the altimeter is of little use and we can only be sure we can fly a piece of the spiral.

The piece of the spiral we aim to fly is the arc between the point abeam the touchdown point (flying downwind) and the point where we intercept the final approach, and we position the aeroplane at the start of this arc at the correct angle to the aim point regardless of our altitude by putting our reference line on it. Obviously the lower we are the closer we will be at the start of this arc, and the tighter will be the spiral and the shorter will be our final approach. Within reason, it doesn't matter, only the angle matters. See Figure Twelve.

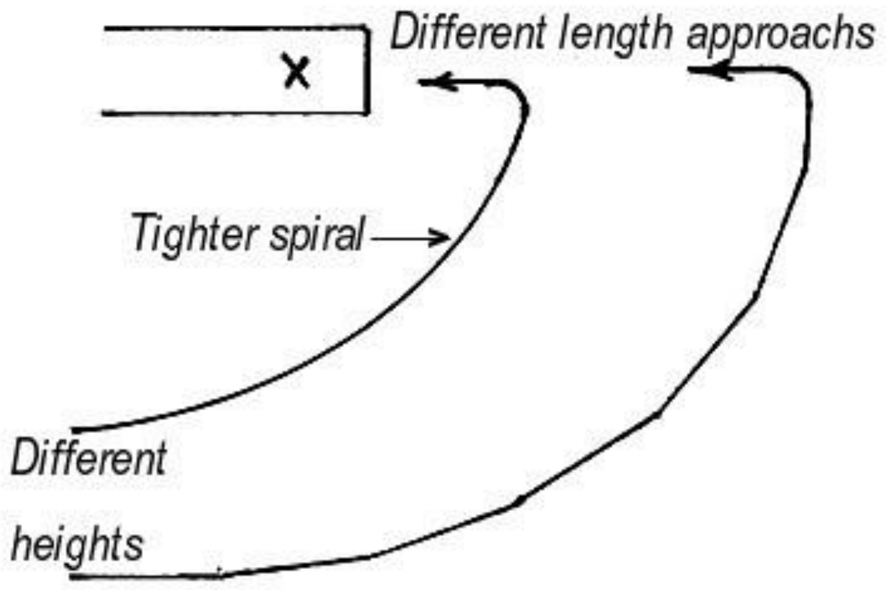


Figure Twelve

During initial glide circuit training I would have my students position the aeroplane abeam the aim point at about 1500 ft above the field. Later I would cover the altimeter and have them fly the funnel from various heights, which is why this technique is incompatible with normal circuit procedures and will not fit in with other traffic.

A little earlier I touched on ‘wind’ and its effect on our perspective. Obviously the wind will also affect the final approach to the field because, just like in the previous lesson on the ‘Approach’ to land, we are aiming to land on a moving aircraft carrier. In light to moderate winds the angle of the funnel will be steep enough to allow for the flattening effect on final, and by keeping the aeroplane on the funnel we will automatically compensate for the motion of the ‘carrier’ before turning onto final approach. See Figure Thirteen. (In very strong winds, say 20+ knots, it may be necessary to fly a steeper funnel by using the next rib line in as a reference, and using an adjusted ARP when on ‘finals’.)

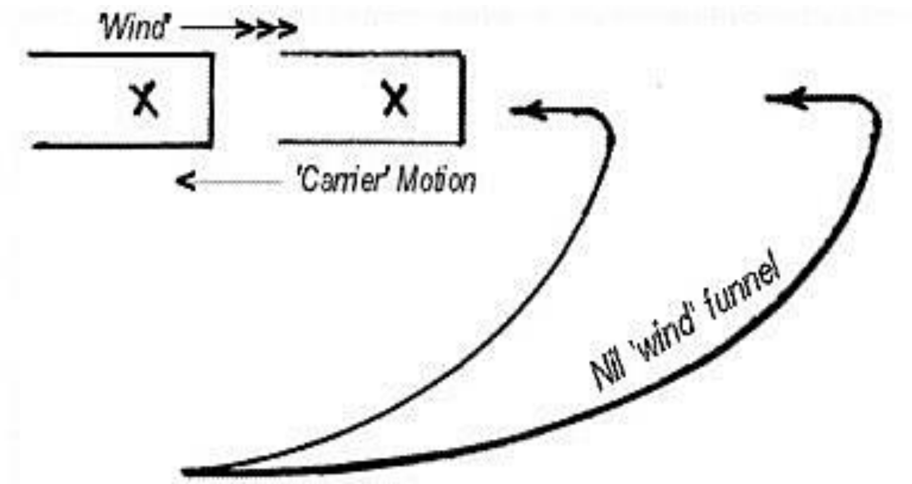


Figure Thirteen

As the wind gets stronger we will find that the aeroplane will have to be turned toward the field long before the aim point has drifted back to the leading edge of the wing in order to keep the aeroplane on the funnel. That’s okay; the rib line on the wing is a reference line when the wings are level. Fly the aeroplane so that the angle to the aim point is similar, regardless of its aspect. See Figure Fourteen.

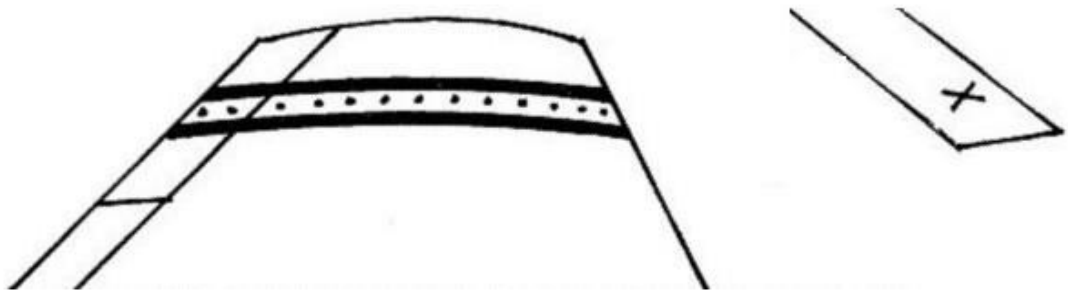


Figure Fourteen. Aim point appears well ahead of wing due to drift angle

What about glide speed? Well as discussed in Book One and again in this lesson it is difficult to determine a specific glide speed in the changing conditions of turning, wind effect, propeller drag and the extra energy requirements, but I have found that about 1.2 times the 'book figure' is adequate. Since this funnel technique automatically compensates for differences in glide speed, propeller drag and wind, if in doubt just hold the (cruise speed) level attitude and the resulting speed will be reasonable. See Figure Fifteen.

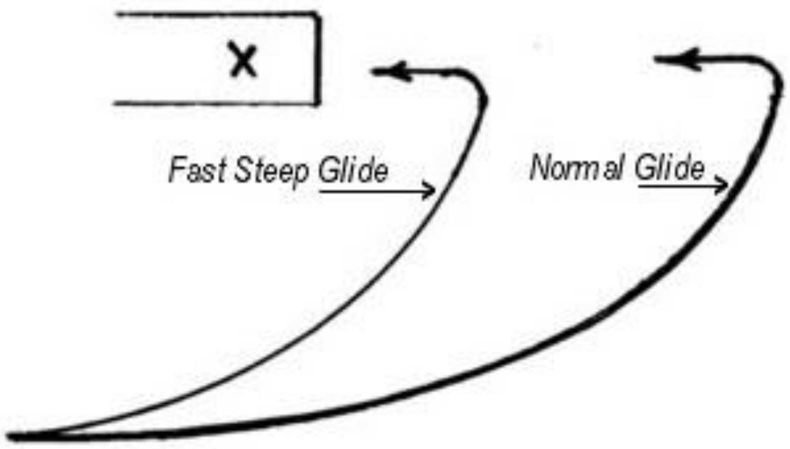


Figure Fifteen

With a little practice this technique will allow you to reliably position your aircraft on final approach to land on any field, in any wind without reference to the altimeter or the airspeed indicator, and it will position you there with sufficient reserve energy to guarantee making it to the field under control. All you have to do is hold the level attitude and turn the aeroplane to keep it on the funnel until you intercept the final approach. Once on final approach, aim the aeroplane at the aim point using the ARP, having set the corresponding increment of flap in the final turn. The airspeed indicator will now show you if you are going to make it. If the speed is steady or increasing you are going to make it; use sideslip and extra flap to achieve the desired threshold speed. If the airspeed is decreasing you are undershooting the field…you need more practice at assessing the funnel!

Once you become competent with this technique you can make bets with your fellow pilots about your ability to glide from cruise height to a chosen point on an airfield, without reference to the altimeter or the airspeed indicator. Make it a game, games are fun and you will therefore enjoy practicing the technique. One day you will need it for real. You will survive but the ostriches will not.

Lesson Six

Forced Landings

The term ‘Forced Landing’ simply means a landing you are forced to make for some reason. It may be because one of your passengers is in dire need of medical attention, or because there has been some problem with one of your aeroplane’s systems precluding the continuance of the flight, or it may be because the weather conditions have deteriorated to the extent that it is not advisable to continue the flight. In each of these cases flying to the nearest suitable airfield and landing there is the most logical action.

There is another reason to make a forced landing, and it is the reason that I wish to address in this lesson, and that is an immediate forced landing resulting from a sudden and catastrophic engine failure, usually requiring a landing somewhere other than a prepared strip or airfield. This situation is commonly referred to as an ‘engine out forced landing’ or a ‘dead stick’ landing. (What the ‘stick’ has got to do with it I have never been able to figure out!)

Obviously once our aeroplane is ‘engine out’ we will have to establish a glide and, after some initial checks to see if the problem can be rectified, head toward a suitable field on which the aeroplane can be landed via a glide circuit. (I will address the nightmare scenario of an engine failure immediately after take of in Annex A.) Two problems will be immediately apparent. The first is the selection of a suitable field to land on in the limited time available, and the second is deciding if it is within glide range of the aeroplane. Let’s address the first problem first.

Most flying schools teach a range of criteria to be considered when choosing a suitable field, most of which, whilst not incorrect, cannot be determined from the height the glide has commenced. Things like surface and slope and obstacles can often only be determined when on final approach, which is usually too late to do anything about the situation, so this part of field selection will always be a bit of a lottery. If you fly in one particular area regularly, check out a number of suitable fields within that area and perform regular engine out forced landing practice on them. This will give you a head start on the forced landing process if you lose the engine in this area. Obviously these fields should be distributed throughout the area so you will always be within range of one of them. Of course when flying ‘cross country’ this cannot normally be done, so we are back to the lottery. However, regular practice on suitable fields in your local area will build up a ‘portfolio’ of images in your brain which can be used as a reference when confronted with the problem of quickly choosing a field in unfamiliar territory. If, from a similar height, it looks like one of the fields back home, there is a good chance that it will be like that field.

Two important criteria which can be assessed from the commencement of the glide are the size of the field and its orientation with respect to the wind. Once again, regular practice on suitably sized fields in your local area will give you a ‘yardstick’ to enable you to quickly assess the size of other fields. What about wind velocity? The forecast wind, the movement of cloud shadows, smoke, dust, and wind lanes on water, all of these things will give you an indication of the wind velocity and this assessment should be carried out before the engine fails! Huh! How can this be done if the engine failure is unexpected? The answer is simple. An aviator should always know in which direction and at what speed the air mass in which he is flying, is moving. This knowledge is part of common airmanship and is useful for so many aspects of flight, not just in case the engine fails. So when flying around looking at the scenery, don’t just gaze idly at it, take in the information it is providing you and know what the wind velocity is. So when the engine does fail you already know the desired orientation of the field you are looking for and your preferred landing direction. All you then have to do is find one that fits these criteria.

I often presented my students with a simple problem concerning the landing direction they would choose on a square field with the wind blowing along one of its primary axis. It was interesting to note that most pilots liked to orientate themselves directly into wind, especially if it was parallel with some observable line feature like the fence line along the edge of the field as shown in Figure One.

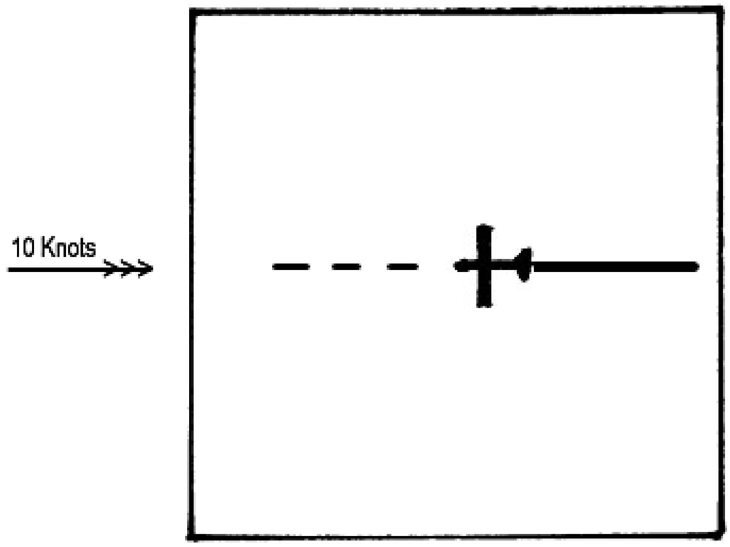


Figure One

In fact the most suitable landing path on this field is diagonally across it from one corner to the opposite corner despite a reduction of the headwind component and a small crosswind. On this field the landing distance available is increased by 40% whilst the headwind component is only reduced by 30% if a landing on the diagonal is made. See Figure Two.

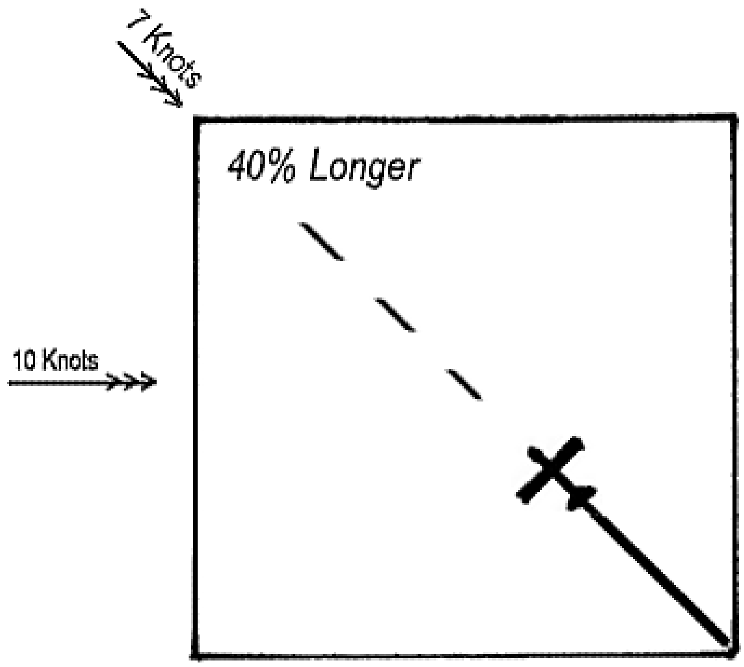


Figure Two

Some simple mathematics will clarify my assertion. Let's assume that we have a 'threshold' airspeed of 70 knots and that the wind speed is 10 knots. Landing directly into the wind would result in a ground speed at the threshold of 60 knots (70-10) whilst landing 45º 'off' the wind would result in a ground speed of 63 knots (70-7). Obviously the ground roll of the faster aeroplane will be greater, in fact about 10% greater, but it has 40% more ground to do it in. The end result is a greater margin of safety to allow for any misjudgment of the final approach.

You can see that choosing the longest landing path across a field is more important than landing exactly into wind, which is good because even though we 'know' the general wind velocity in advance, it can only ever be an approximate figure because of 'local' effects.

Okay, now to the second problem, is the field within 'safe range'? What do I mean by 'safe range'? Safe range is a range which allows a moderate overshoot potential thereby keeping sufficient energy in reserve to guarantee not undershooting. There may be a sealed runway at the theoretical limit of your aeroplane's glide range, seducing you to 'have a go', and which under ideal circumstances would enable you to 'pull off' the perfect forced landing. But the undershoot area may contain buildings and trees and other 'hard' obstacles which could terminate your life instantly. In the words of Clint Eastwood's 'Dirty Harry', "Do you feel lucky? Well do you?" Surely it is better to select a landing site that, whilst not perfect, offers the greatest chance of survival for the people on board. A controlled crash can be a better choice than a 50/50 chance to live or die. (That's 'Russian Roulette' with a half loaded gun!) See Annex B for more on this philosophy.

So the chosen field is within safe range if we can arrive in the vicinity of the field with enough height to fly a glide circuit. How do we assess this? Let's look at the 'Funnel' we discussed in the last lesson, from a different perspective. Instead of imagining we are on the rim of a funnel we imagine we are the centre of an inverted funnel defined by the same reference lines on the wing that we saw in the previous lesson. The area of ground defined by this inverted funnel is the area in which we search for a field which fits the previously mentioned criteria. See Figure Three.

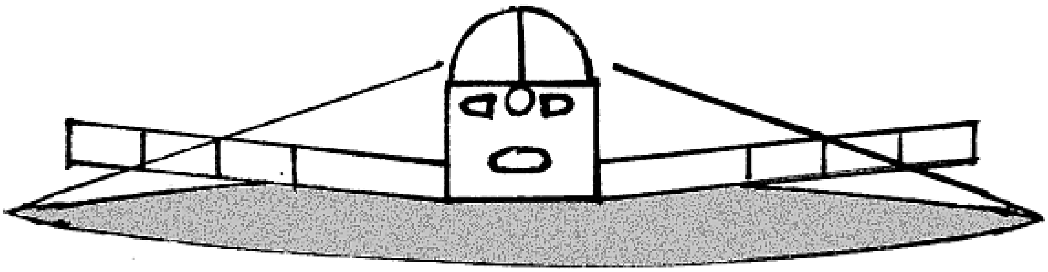


Figure Three.

As height above terrain increases the area on the ground, defined by the funnel, increases exponentially. That is, at twice the height the defined area is four times as large. So obviously the higher you fly the greater are your chances of locating the 'perfect' field within safe range. See Figure Four. (I have steepened the angle of the funnel in this picture for clarity.)

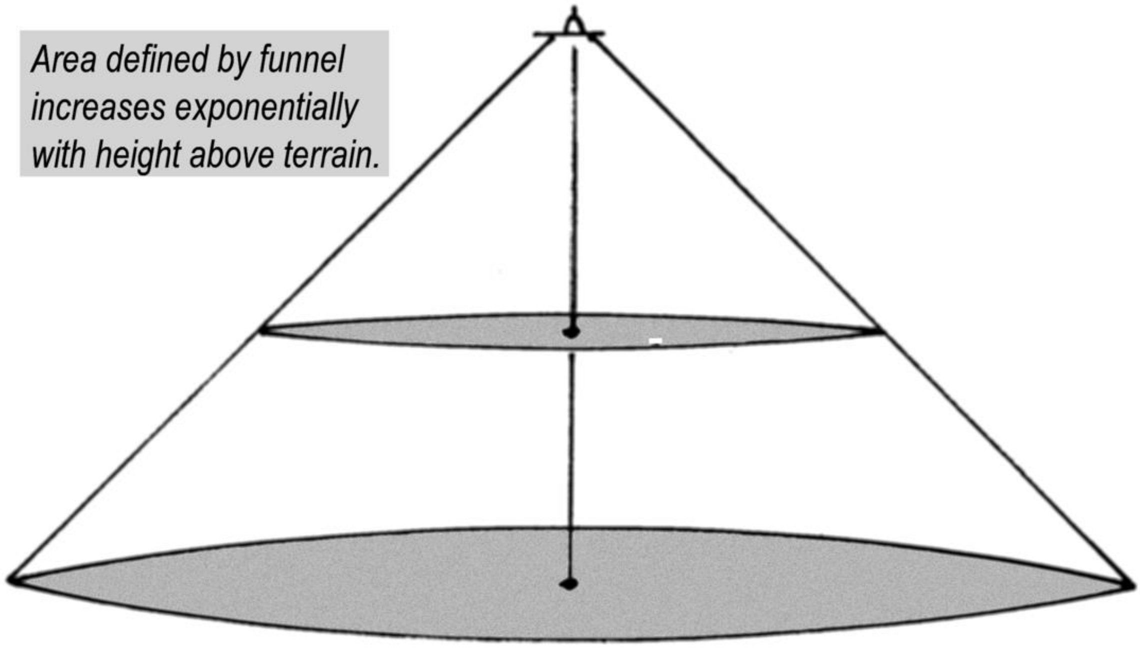


Figure Four

The wind will affect this area too. I like to use the analogy that the inverted funnel is like the hoop skirt of a ‘Southern Belle from Georgia’, walking down a path on a windy day (Mint Julep in hand). The skirt will be blown downwind and so will our defined area. So when searching for a suitable field you will have more options if you search downwind from your present position. You will also be better set up to join the glide circuit on the downwind leg. See Figure Five.

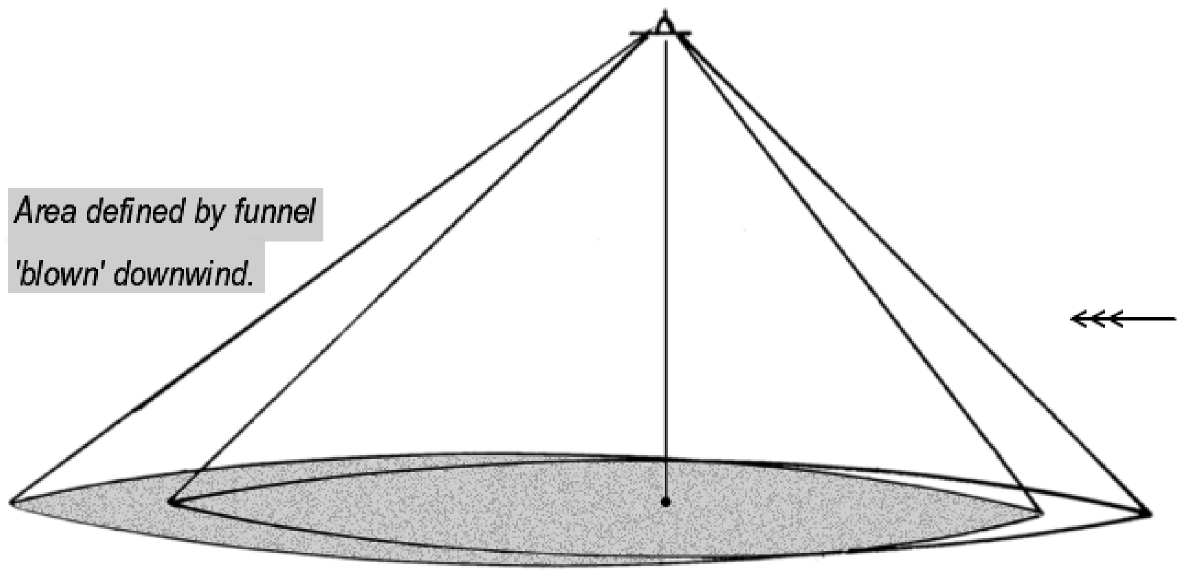


Figure Five.

Once the field is chosen and the landing direction defined, turn the aeroplane (don’t pussy foot) and head toward a position about one mile abeam the landing path at the best range glide speed. As this position is approached pick an aim point about 200 meters in from the approach threshold and manoeuvre to put this point at the same angle as the reference line on your wing. Note; this one mile point is only an initial guide. Since you don’t know what height you will be when you are abeam the landing path, you don’t know what distance you will be from the field when you get there and establish the correct angle either. It doesn’t matter! This is the whole point of the funnel technique. As you approach abeam the field the one mile point will have vanished under the nose but the aim point will be approaching the leading edge of your wing (low wing aeroplanes) enabling you to pick up the funnel to start the glide circuit (at the higher speed discussed in the previous lesson).

Obviously every landing path has two potential one mile points, one to start a left circuit and one to start a right circuit. See Figure Six. Which you choose will depend upon how close each one is, and I don’t mean that you should always choose the closest. If you have chosen a suitable field quite close to the aeroplane you may decide to over fly it and pick up the glide circuit from the other side to avoid being too ‘cramped’.

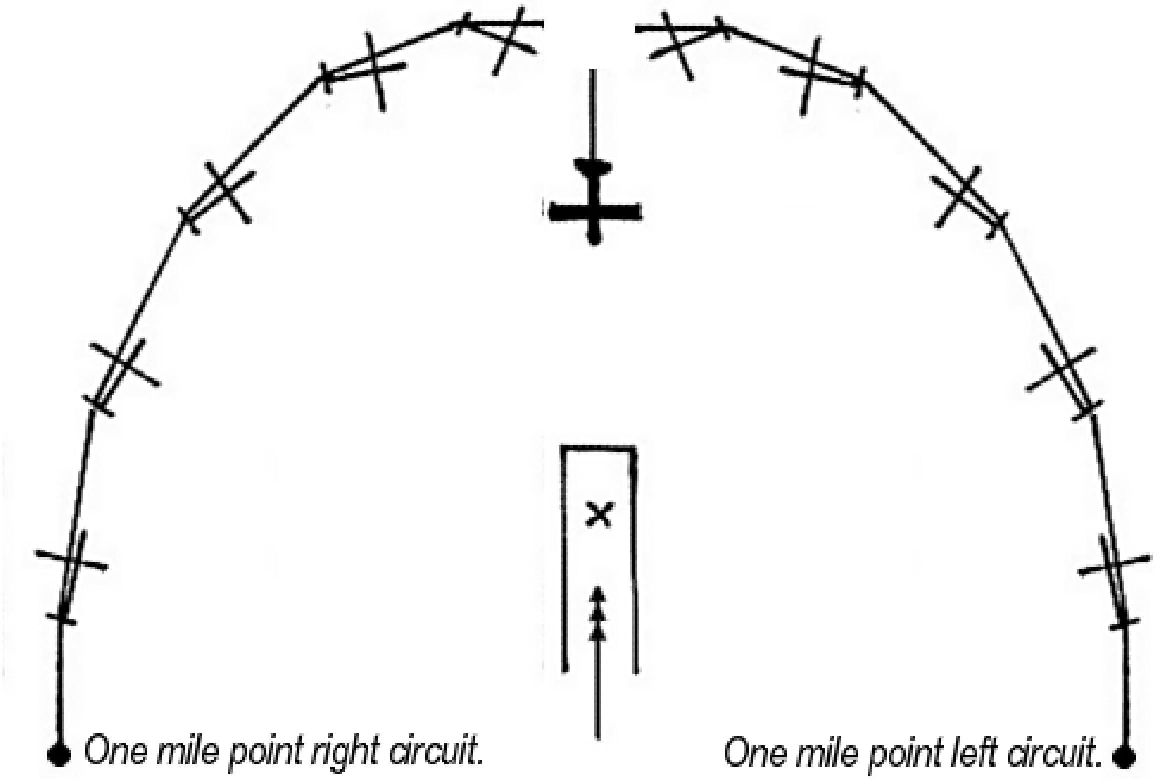


Figure Six.

Practicing this technique on your favorite fields in your local area from different starting points will give you a wealth of experience on the best way to arrive downwind for the glide circuit. If you are positioned at the outset so that no one direction of circuit is favored then a left circuit will ensure you get the best view of proceedings, as that is the side that most pilots sit, in side by side seat aeroplanes.

What if you have chosen an ideal field but it is upwind of your position at the point of engine failure? It may seem like you are 'wrong footed' to set up a glide circuit in these circumstances. Not so! Simply glide toward the one mile point as if you were going to land in the opposite direction and when you get there make a 'U' turn. Use at least 45º of bank for this turn, and turn toward the field. The height you lose in the turn will be compensated by the turn diameter which will move you closer to the field thereby keeping you on the funnel. I refer you back to the discussion on gliding turn rates and radius versus rate of descent in Book One - Lesson Nine, 'Gliding', for the reason why you should use such a high bank angle. Remember, don't 'pussy foot'.

Alternatively, if you are sure you have enough height, glide directly over the field, heading upwind and then make a moderate bank turn to the downwind leg, adjusting the bank angle in the latter part of the turn to arrive on the funnel heading downwind. Refer to Figure Seven.

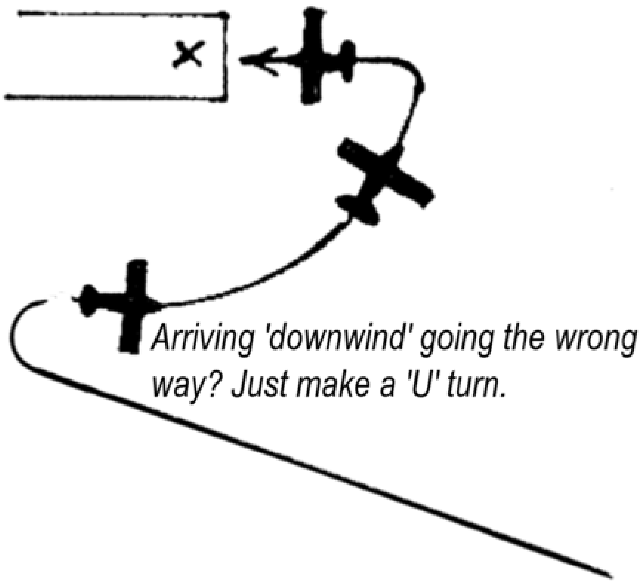


Figure Seven (a)

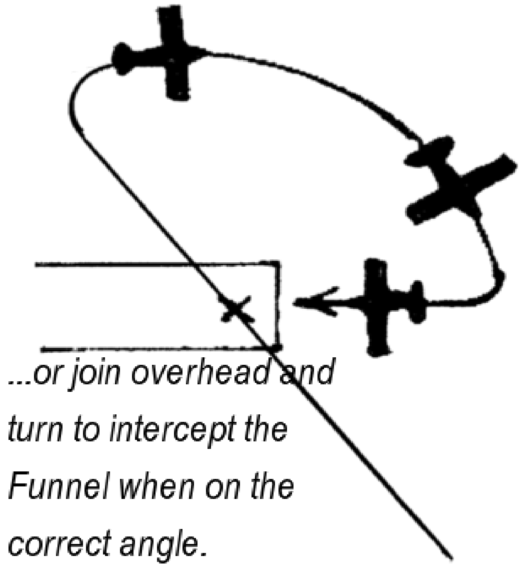


Figure Seven (b)

You will note that throughout this lesson I have used the word ‘height’ not ‘altitude’. That is because altitude is what you read from your altimeter and it is measured from sea level not from the elevation of the field you have just chosen! You won’t know your height because you won’t know the elevation of the field. Sure, you will have a general feeling of high or low (particularly low when you can see the individual leaves on the trees) and this will assist you in deciding which one mile point to go for, but once you are in the vicinity of the field just fly the funnel, don’t try to estimate your height and ignore the altimeter, just fly the funnel.

Along the way between making all of these decisions and arriving at the start of the glide circuit, you should double check everything to do with fuel, air and spark to see if power can be regained. You should also put your passengers in the picture too, and the best way to do this is to talk out loud whilst making the initial decisions and doing these engine checks; this way they can both see and hear that you are busy and won’t interrupt you. (Talking out loud will also help you to remember those engine checks too.) Finally, when it is obvious that you are not going to get the engine running again, you should make a distress call on the radio to alert the search and rescue people that you may need their assistance. (Your passengers will hear this too.) The international distress call is detailed in the aviation publications of every country so I won’t repeat it here, but I will say that this is not the time for a friendly chat with air traffic services – they can’t fly the aeroplane – only you can do that.

I have seen and heard pilots in both practice and real situation get so hung up on saying things correctly and then replying to the responses they get that the glide circuit goes ‘out the window’ and the whole thing becomes a disaster. All you have to say in a loud clear voice is “Mayday” three times and your “Call sign” three times. The guy on the ground at the other end of the transmission then has plenty of time to work out the meaning of what he has just heard. I am assuming that, for local operations, someone at the departure field (like your aero club or flight school) knows the area in which you are operating, and if you are on a cross country flight you have filed some sort of flight plan with the air traffic services. As long as the guy on the ground has your call sign he can then track down where you are most likely to be…that is his job. Your job is to survive, and if you do your job properly you can phone in the details of your 'incident' from the nearby farm house.

Of course carrying one of the new 406 Mhz Emergency Locator Beacons can alleviate all of this radio chatter; just activate the beacon and let the GPS satellites alert the rescue services and locate you.

Now all of these extra things have to be done in only a couple of minutes between turning toward your chosen field and starting the glide circuit. Never let any of them spill over into the glide circuit part of the procedure, the glide circuit requires your absolute concentration because you now only have about another two minutes to determine whether you and your passengers are going to live or die!

Annex A: Engine failure after take off!

Annex B: Some further thoughts on surviving an engine failure

Annex A

Engine Failure after Take Off!

Probably the worst scenario for an aviator, except perhaps for an in flight fire, is an engine failure shortly after take off. Statistics of aircraft crashes involving fatalities show that this is an extremely hazardous situation and one that demands careful thought before each and every take off. An engine failure after take off is clearly a 'worst nightmare' situation, yet most pilots adopt the ostrich approach and bury their head in the sand and don't think about it. ("Praying to God and Pratt & Whitney" is a phrase I have heard more than once.)

The standard teaching for this situation is "land straight ahead, never attempt to turn back to the field" and yet so many pilots faced with this situation have attempted to turn back, usually with disastrous result. Why? Well obviously at many airfields which are surrounded by buildings, houses and other obstacles there are no suitable places to land straight ahead into, so the pilot tries to make it back to the only flat piece of ground around and fails. I have often heard the argument, "well if he knows he is going to die anyway he might as well give it a shot". Fair enough, acts of desperation go beyond reason; however, if this pilot had had some more training in what was possible and what was not, he might have been able to make a better choice of where to go to make a controlled crash and maybe survive.

I wish to discuss some considerations and suggest some training exercises which can help you make better choices if this nightmare happens to you.

First I ask the rhetorical question: "when is an aeroplane no longer 'after' take off?" When we are cruising at three or four thousand feet we are certainly 'after' take off, but at what point is it obviously possible to make a 180º turn? That is, where does the take off phase of flight end? There is no simple answer to that question as it depends upon the performance of the aeroplane (and the pilot) but since I am going to suggest in a moment that in certain circumstances turning back to the field is possible, and to avoid the mountain of incredulous responses I will get from readers for even suggesting that the 'golden rule' of "never turn back" can be violated, I am going to coin my own definition of where the take off phase ends.

"The take off phase of flight ends when it is possible to turn back to, and land on, the departure field".

This definition now begs the question; "When is it possible to turn back?" I repeat that it all depends upon the performance of your aeroplane and you. So now that I have side stepped the issue of "never turn back" let's discuss how you can determine what is possible for you.

In Book One - Lesson Nine, 'Gliding', I discussed height loss versus rate and radius of turn whilst gliding. If it has been a while since you have read it, go back and read it again now. Then, based upon the theory contained in that lesson, try the following flying exercise in your aeroplane.

At a comfortable height above terrain (say 2-3000ft) establish a climb along a clear line feature like a road. When your altimeter passes a convenient figure, say 3500ft, close the throttle, immediately lower the nose to the glide attitude and roll into a 45º banked turn. Note how much height has been lost as the turn passes 180º (the road on a reciprocal heading). It will probably be somewhere between 300 and 400 feet. Do it several times and note the greatest height loss. (If you doubt that 45º bank is better than some lesser angle of bank, try it with a reduced angle of bank too, say 30º, and see how much height you lose.) You should become comfortable with making gliding turns with this much bank and become sure of your height loss whilst performing them from a climbing start.

Does this mean that a turn back to the field can be made from this height above the field on the upwind leg? NO! There are other factors to consider. After you have practiced this manoeuvre a few times you will note that your height loss at the end of the exercise is less that on your first attempt. This is normal, you are getting better at flying the manoeuvre and you are anticipating the 'engine failure'. In reality, the engine failure, when it comes, will come as a surprise and you will not react as quickly as you did in practice, so add 100ft to cover this slower reaction time. Then having completed the turn you should allow about 100ft of straight final approach to properly configure the aeroplane before touchdown. So add another 100ft. We now have a figure that in ideal circumstances will represent a height from which you should be able to complete a 180º turn following an engine failure after take off.

But is this going to guarantee a safe landing after the turn? Not necessarily. Consider this. If you have taken off from a field which, whilst a suitable length for your aeroplane, is not too much longer, the point at which you reach your turn back height will be well beyond the end of the runway and this is the point you will now be over/abeam at only 100ft after you have completed the turn! Are you now high enough to be able to glide back to the field? Probably not, despite the fact that you may have a tailwind. Obviously using the entire runway available to you for take off will alleviate this problem somewhat, but not always. (Unless you operate from a field that is more than twice as long as you need for take off your chances of making it back to runway in a normal GA aeroplane are close to zero!) See Figure Eight.

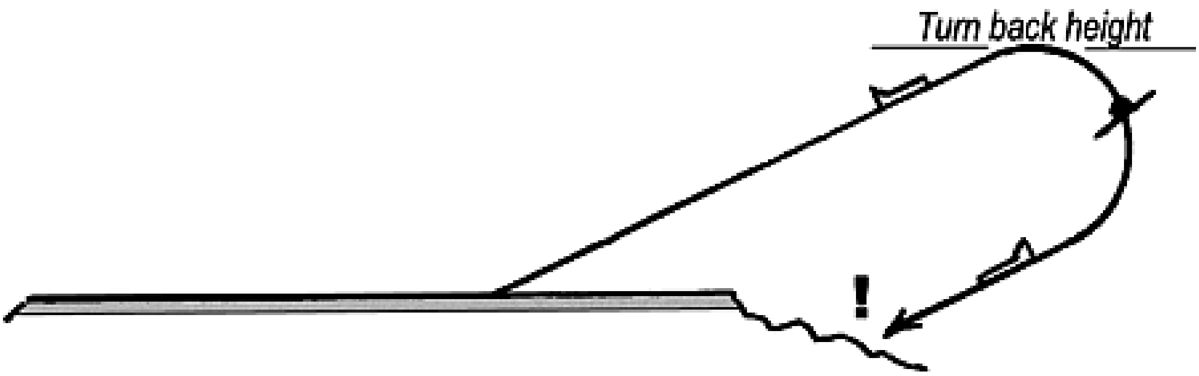


Figure Eight: Side elevation of a turn back manoeuvre.

Climbing at optimum from lift off to turn back height is also essential. Almost daily I see and hear aeroplanes fitted with constant speed propellers reducing power at a height of about 100ft after take off because, according to their pilots, it “saves the engine”. If you want to save the engine don’t put it in a situation where it may become a grave digging machine 100 meters short of the runway following a turn back! Yes the manufactures of most engines put a time limit on how long they should be operated at full power; it is usually around five minutes. This is more than enough time to reach turn back height. So, use full power for take off and maintain full power whilst climbing at optimum speed until you reach turn back height.

A question which should have popped into your mind at this point is: “What is optimum speed? Do we use best rate or best angle of climb speed up to turn back height?” Good question. Let’s analyze it for a moment. Best rate of climb speed will get you to height quicker but you will be further from the field after the turn back , and best angle of climb speed will take longer to make turn back height but you will be closer. If you have forgotten why this is so, I refer you back to Book One - Lesson Eight, ‘Climbing’. Obviously if the engine fails at a specific time after take off then it would be better to be as high as possible, so best rate is the speed to go for. If you have made it to turn back height with a best angle climb the situation will not be any better because the aeroplane will be slower and will lose more height in the turn as it accelerates to minimum drag speed at 45º of bank. So theoretically climbing at best rate speed is preferable, but hey, don’t take my word for it, go out and try it for yourself, (at a safe height).

Of course, making a 180º turn will, in most cases, not be enough to align you with the runway because the diameter of the turn will have displaced you from the extended centerline of the runway. A turn of 210º one way followed by a 30º the other will be needed to properly align you with the runway. How much extra height will you need for that? Try it and see. See Figure Nine.

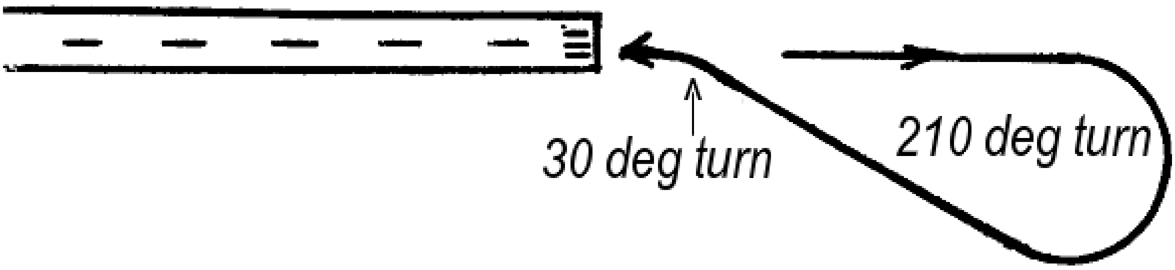


Figure Nine: Plan view of turn back

If you have taken off with a crosswind, then making the initial turn into the crosswind will reduce the turn radius over the ground somewhat and therefore reduce the total number of degrees you have to turn, too. This reduction will of course depend upon the strength of the crosswind and will therefore affect the minimum acceptable turn back height (a little). See Figure Ten.

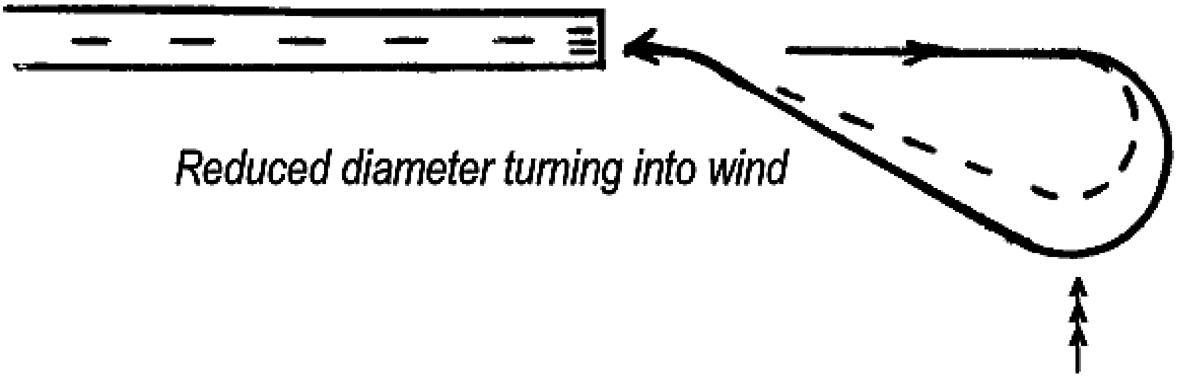


Figure Ten: Plan view with crosswind.

If you are operating from a field where the traffic pattern will allow it, another option is to make a 20-30° turn off runway heading using about 10° of bank once the initial climb is stabilized. This turn should be made away from the prevailing crosswind and will establish an offset from the extended runway centerline equal to the turn back diameter as the turn back height is reached. See Figure Eleven.

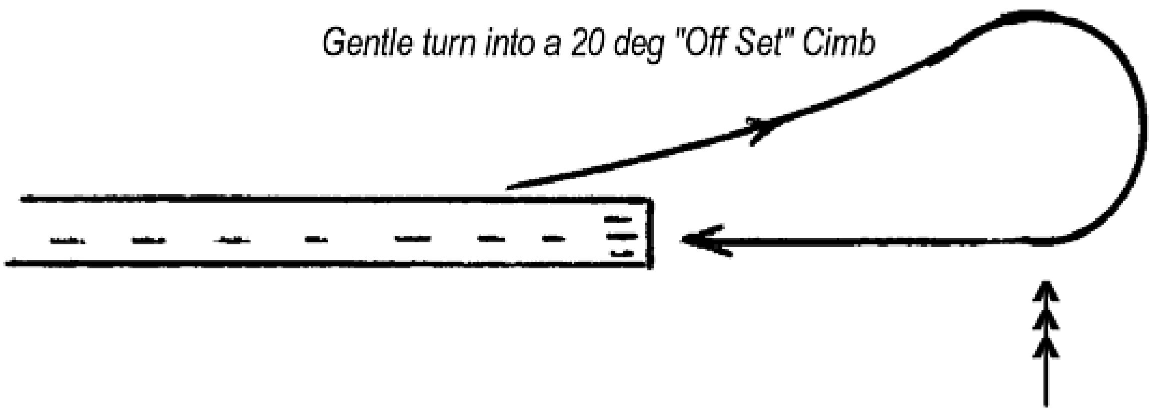


Figure Eleven: Offset climb

This ‘offset climb’ technique is particularly useful on high powered but high drag aeroplanes like my Pitts S2S, which climbs like a rocket and glides like a house brick! Eliminating the ‘S’ turn to final makes a significant difference to the height loss during the turn back manoeuvre.

If you have the ‘luxury’ of departing from a field with multiple runways, you will have the option of turning back to one of the other runways. This possibility will reduce the height from which a turn back can be made compared to a single runway airfield. See Figure Twelve.

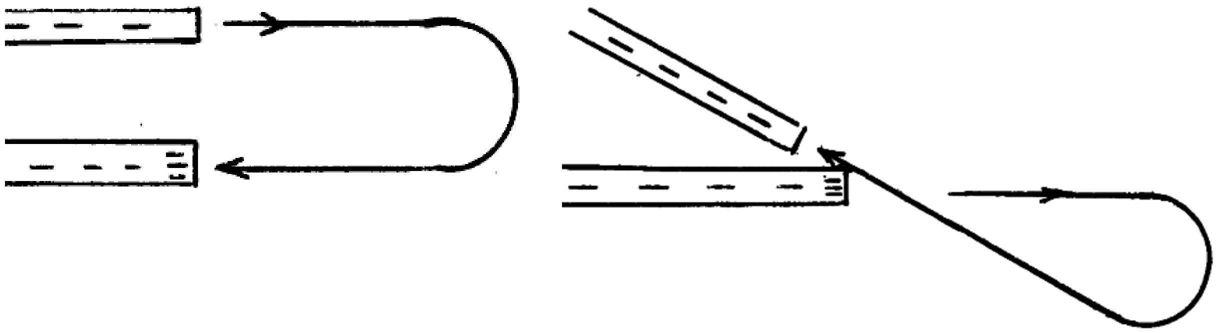


Figure Twelve: Multiple runway options.

Alternatively, landing diagonally across the real estate on which all of the runways are built is also a possibility. ‘Taking out’ a few runway markers and lights is preferable to taking out the local shopping mall! Obviously turning in the direction of the greatest amount of airfield is more important than the direction of the cross wind. See Figure Thirteen.

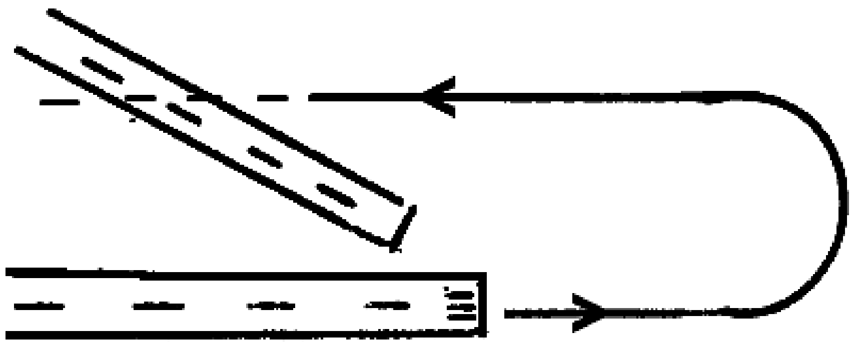


Figure Thirteen: Landing on the airfield and across the runways!

If you are arriving at a field that is new to you, make an ‘overhead join’ and check out the terrain and obstacles off the departure end of the runway and file the images into your memory bank for use prior to your take off from that field.

So now that we have determined our minimum turn back height, the most efficient way to get there, and the most efficient way to make the turn, we are still faced with the question, “why risk it?” It is a limit manoeuvre which leaves no room for error, so a controlled crash off airport may still be the best option. In Annex B I discuss this balance of risk decision and give a couple of examples.

There are a lot of variables to consider, so when do we decide which option to go for? After the engine failure? No way! There isn’t time; you are about 30 seconds away from landing…..somewhere!

All of these variables have to be considered and factored into the calculation of a potential turn back height before take off! During your pre-take off briefing decide what height you are going to use, which way you are going to turn and which runway or landing path you are going for. If the engine fails below this height DO NOT attempt a turn back. Focus on making the best controlled crash that you can off field somewhere.

Obviously the higher you are the more you can turn off runway heading to achieve a landing in the ‘softest’ area. Practice these scenarios too, from say, 200 – 400 ft above a safe reference height, so that even though you are too low to turn back you will have an idea of how far you can turn to achieve your objective rather than just “landing straight ahead”.

Surviving an engine failure shortly after take of will involve some positive attitude changes and some positive manoeuvring. Having an attitude reference point marked on the windscreen prior to take off will assist you in quickly establishing the attitudes required and aiming the aeroplane at your touch down point thereby reducing the necessity to look inside the cockpit to check the aircraft’s performance.

As I said at the beginning of this lesson, an engine failure after take off is an extremely hazardous situation to be in. Confusion about which course of action is possible and which is not increases the risk of a disastrous outcome. Fly the exercises I have suggested so that you know what is possible and think through the options before each and every take off. Doing this will at least help you focus on achieving what is possible from the outset and improve you chances of survival.

Many years ago I was flying a beautifully restored Tiger Moth belonging to a friend, out of a grass airfield near the town of Bowral, south of Sydney Australia. At a height of 400ft, just short of my turn back height, the engine suffered a major internal mechanical failure; it lost power and started shaking so much that all of the instrument needles became a blur. I instinctively closed the throttle, lowered the nose and rolled into a left turn toward an open field 90º off to my left which I had pre-selected on arrival. The field was dotted with trees and whilst I had a clear touch down area I did not have a clear roll out path so I figured one of the wings was in for a beating. Once I realized that this imminent controlled crash was survivable my next thought was "Ken (the owner) is going to kill me if I break his beautiful aeroplane." I then noticed the end of the runway out of the corner of my eye; it was only just outside of what I assessed as the glide range of the Tiger, which was turning rapidly at this stage. I shoved the throttle wide open again and despite the violent shaking, felt a small increase in thrust. I elected to continue the turn and to let the engine shake it self to pieces if necessary as long as it gave me a few more seconds of thrust.

The Tiger's tailskid caught the top strand of the airfield perimeter wire fence, which, fortunately, yielded and the old girl touched down and stopped in the 200ft of over-run area short of the actual runway, trailing ten meters of fencing wire but otherwise unscathed!

Even though I had experienced several engine failures in flight prior to this, this was my first one 'after take off'. We were fortunate that the dear old Gypsy Major engine still gave out some power for the next few seconds and saved the Tiger Moth's wings from being ripped off by a tree. The thing I learned most from this experience was that once you know that you are going to survive you are able to focus more on the flying. Nothing clouds the mind more than the fear of imminent death! I also learned that there is time to reassess the situation once the turn is in progress. If, half way through a turn back manoeuvre, you don't like the look of the situation you can always stop the turn and land straight ahead.

Afterwards I realized that I should not have allowed any thought of saving the aeroplane to enter my head as it no doubt influenced my decision to continue the turn. I put myself and my passenger at greater risk. I was lucky; you may not be when your turn comes. Survival of those on board <u>must</u> have absolute priority.

A pilot who learns everything that his aeroplane can give him is an aviator, a pilot who demands one iota more is a fool!

Annex B

Some further thoughts on surviving an engine failure

I am often asked what I think of aero club competitions which award points and trophies for making the ‘perfect’ simulated engine out forced landing, usually onto a grass runway with good approaches. Surely they must be good training? But I must admit I have mixed feelings. As long as the participating pilots realize that it is a fun competition which bears little relationship to reality then that is okay, but I have sat on the judging line of these types of competitions and seen aeroplanes arrive over the threshold ‘hot’ and watched them float 200 meters before touching down resulting in a very low score, whereas I am sitting there saying to myself “good safe approach, now throw it on the ground and stop it”, which of course is something the pilot will not do as the aeroplane has to be used again. The pilot of course believes that she has done a lousy forced landing and vows to do ‘better’ next time, when in fact her approach had a better chance of the occupants surviving than if she had attempted to gain the perfect score.

I have also watched a number of other pilots in these same competitions, undershoot the runway whilst striving for the perfect score and afterwards saying “ho hum, I will do better next time”, without realizing that if this was a real situation there would be no ‘next time’ because they could be dead. So I feel that these competitions cause the inexperienced pilot to believe that engine out forced landings are an academic flying exercise rather than a survival skill, and therefore won’t have the right mental attitude when faced with a real engine out situation. Hopefully what I have written in this lesson will cause them to rethink their priorities…. “Score or live? Hmmm, let me think about that”.

In the main text of this lesson I made the statement that a controlled crash can be a better choice than a 50/50 chance to live or die. (That’s ‘Russian Roulette’ with a half loaded gun!) A recent, widely publicized and perfect example of this philosophy in action was the ditching in 2009 of US Airlines Flight 1549 into the Hudson River in New York, USA. Having suffered a double engine failure shortly after take off, the captain was faced with a choice of a straight and theoretically possible glide to a nearby suitable sealed runway, which was in plain sight, or ditching in the Hudson River. At first glance the choice seems obvious, go for the runway! However the approach to the runway was over a built up area of the city and even the slightest ‘undershoot’ would have resulted in a total disaster for everyone on board plus a number of unsuspecting people on the ground. The alternative was a smooth uncluttered waterway 8 miles long and 1/2 a mile wide, as straight as any runway and only a 90º turn to the left. The river at this point afforded miles of under shoot and overshoot potential and it afforded the captain the opportunity to make a controlled ditching on a smooth surface, without obstacles, and virtually guarantee survivors. The transcripts of the cockpit and radio communications during this emergency reveal the voice of a focused aviator who ignored most of the well intentioned transmissions from the tower as they were irrelevant to his purpose. The result of his decisions and actions is legend.

Many years ago a very good friend of mine was an observer in a Cessna 210 involved in an air search in a water filled valley west of Sydney. There were a total of six people on board. Without warning the engine suffered a catastrophic internal failure, covering the windscreen with oil and causing the oil pressure to drop to zero. An immediate ditching along one of the shores of the reservoir assisted by the power still available from the engine would have ensured the survival of everyone on board. (A Cessna 210 with the wheels ‘tucked up’ is a little flying boat and has very good ditching characteristics. This has been proven in many other ditchings of this type.) Because the engine at that stage was still delivering power the pilot in command elected to climb out of the valley and attempt to fly to a small airfield about 6 miles away. Half way there the engine seized and the aeroplane came down into trees. The pilot and my friend and two others were killed and two were badly injured. It didn’t have to end that way.

As I have said many times in these lessons, the aim of the game in an engine out forced landing is survival. Nothing else matters, nothing. The aeroplane certainly doesn’t matter; it has just let you down by causing this situation, so it is expendable. Use it; abuse it, but walk away from the wreckage.

I have, over the years, expressed my philosophy many times at flight instructor seminars and CFI’s conferences etc. It never fails to cause great argument. I find those raising the greatest objections are those who have not yet had to do it for real. I have done it ‘for real’ a dozen times and I know what my priorities are. What are yours? Think about it. Let me finish with a pertinent quote I particularly like.

“The aircraft limits are only there in case it is likely that there will be another flight by that particular aircraft. If subsequent flights appear unlikely, there are no limits!”

Lesson Seven

Your Wings

In Book One – Lesson Six, ‘Stability and Control’, I introduced the simple **aerodynamic** relationship between the (negative) angle of attack of the tailplane and the (positive) angle of attack of the wing. In Book One - Lesson Eleven, ‘Stalling’, I expanded upon this relationship to include the stick position and its control of the angle of attack of both the tailplane (mechanically) and the wing (aerodynamically). I included a diagram of this relationship which I have reproduced here as Figure One.

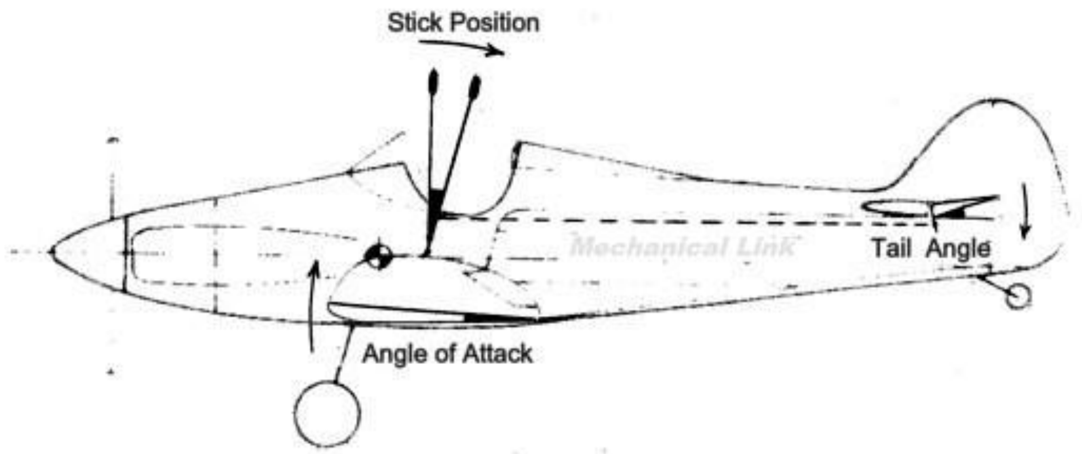


Figure One

In that lesson I emphasized this stick position/angle of attack relationship with particular respect to stalling. I also mentioned that this relationship applies to all angles of attack, not just the critical angle. Of course the angle of attack variations when rolling have a more obvious direct relationship to the stick, because the ailerons are also **‘mechanically linked’** to the stick. So putting the aerodynamic relationship and the mechanical relationship together, as a more general principle we can say:

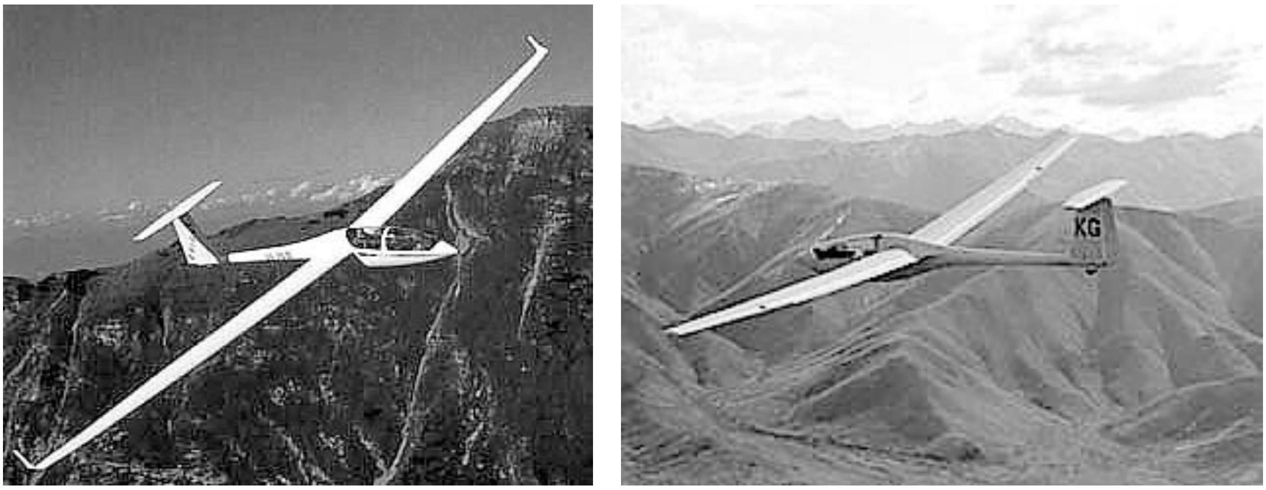
You *have direct control of the angle of attack of the wings of the aeroplane you are flying, both symmetrically and asymmetrically, at all speeds, and in all attitudes, in the air!*

I call this principle ‘Direct Angle of Attack Control’. I also said that the way to establish a ‘hard wiring’ of this principle to your brain is to explore the stick position and angle of attack relationship of your aeroplane in various attitudes and at various airspeeds. It is this exploration that I wish to develop further with this, and the following lessons. I wish to describe to you how to begin applying this principle to your flying whilst remaining within the manoeuvre envelope of your aeroplane at all times.

Now, many ‘skydivers’, (you know, those crazy people who jump out of fully serviceable aeroplanes for fun) have, in recent years, strapped small wings onto themselves or worn special ‘wing suits’ in an attempt to fly like birds. These people regard aeroplanes as big, clunky, awkward machines that the pilot has to ‘wrestle with’ for control, whilst they regard their attempts at flight more ‘birdlike’, because they claim to be more in contact with their ‘wings’. (Despite the fact that they are, unlike birds, actually dropping like a rock!)

Skydiver’s ‘Wings’ and ‘Wing Suits’

Aeroplanes may have been clunky and awkward once, in the early days of aviation, but not anymore. Indeed, modern sailplanes are the most elegant and efficient aircraft ever created, and being ‘in contact’ with the wings of a modern aeroplane is no longer a wrestling match but an exercise of feel and finesse.



Modern Sailplanes

Unfortunately, misconceptions about an aviator's relationship to an aeroplane and its wings are still prevalent amongst most pilots and instructors, and these instructors then pass this wrong attitude to flying along to their students who in turn pass them on…..etc, etc.

Consider this: a bird does not have an instrument panel mounted on its beak to help it gauge its performance. It feels the changing pressure of the air against its wings as it changes airspeed and angle of attack, and it feels the angle of attack directly in the same way that you can feel the position of your arms and hands. Remember when you were a kid poking your arm out of the window of a moving car and feeling the airflow past it. Wouldn't it be great if we could feel airspeed and angle of attack just like that; just like a bird does?

Over the years mankind has developed many prosthetic devices to either replace lost limbs or to enhance the performance of people with all of their limbs. Wheel chairs and artificial arms and legs fall into the first category, whilst bicycles, water skis, roller blades, skate boards and many other similar simple devices fall into the second. The wearers of these prosthetic devices can, with a little practice, operate them as extensions of themselves, controlling them with little conscious thought. Why not develop prosthetic wings that we could operate the same way, just strap them on and fly without conscious thought!

Well…..we have! They are called modern aeroplanes!

But! You may exclaim, aeroplanes are much more complicated than a bicycle, and bicycles only manoeuvre in two dimensions whereas aeroplanes can manoeuvre in all three. So how can the apparently complex controls of an aeroplane be considered a 'simple' prosthetic interface between our brain and an aeroplane like those of a bicycle? To answer that question lets go back to the basics of flight and consider what each control actually does. I am going to change a few of the common names/descriptions of each of the primary controls so that we can have a fresh view of their purpose and use.

The Butt Connector.

The butt connector is simply a sturdy seat which partially raps around and supports the prosthetic operator in the seated position and can comfortably sustain manoeuvre loads up to +/-6G or more. This seat has a harness which straps the operator firmly to the seat and secures him throughout all manoeuvres in order that he may sense the varying forces the aeroplane is subjected to during these manoeuvres. The seat should also be positioned such as to allow the operator to easily reach the other prosthetic controls with the appropriate limbs. This Butt Connector is no different in principle to the attachment of a prosthetic arm or leg which has to be firmly strapped to the stump of the limb it is replacing. You could think of your butt as a stump. This idea gives rise to the time honored phrase “flying by the seat of your pants”.

The Angle of Attack Control.

The angle of attack control is the primary control of our prosthetic wings. It can be a simple stick pivoted on the floor and long enough that the operator can reach and hold the other end and move it freely about. The fore and aft movement of the stick progressively adjusts the angle of attack of both wings whilst its lateral movement progressively adjusts the angle of attack of each wing contrary to the other. **Because the stick can be moved in any direction and by any degree, the operator, by simply moving the stick, can affect the angle of attack of the wing to any degree, either symmetrically or asymmetrically or in any combination thereof at any time or in any flight attitude to direct the aeroplane into any flight path desired.**

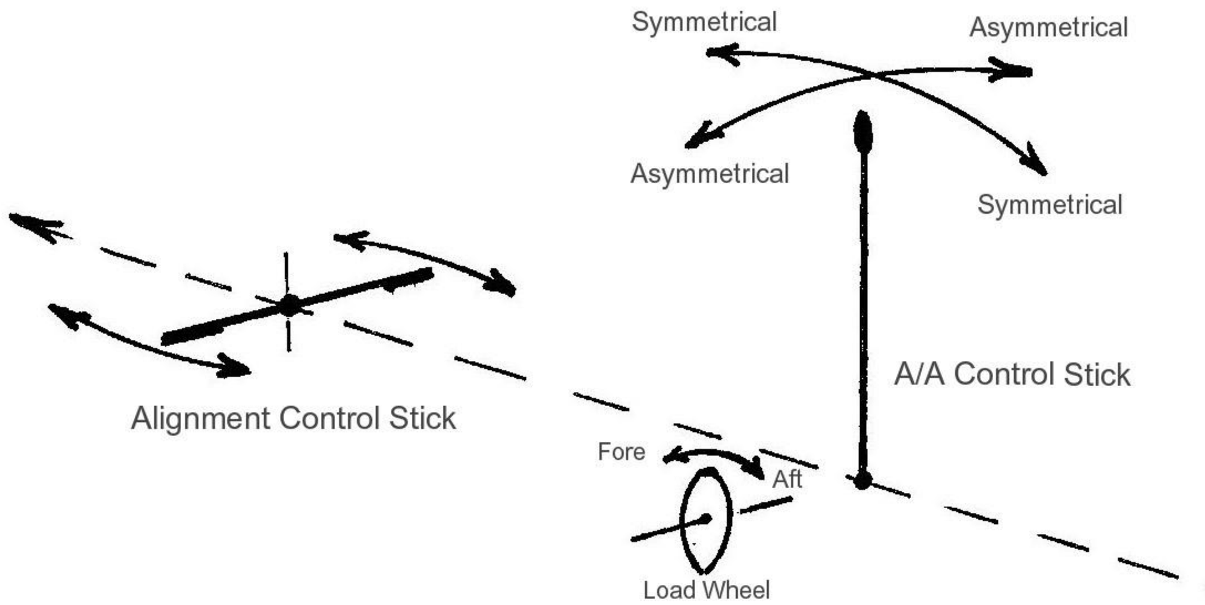
To help the operator assess in which direction and to what degree he should apply the angle of attack control, in addition to his natural orientation senses (ie: which way is down and which way am I turning) **he can also use the ‘back pressure’ or the resistance to the movement of or holding the position of the stick, to gauge speed through the air.**

Load Wheel.

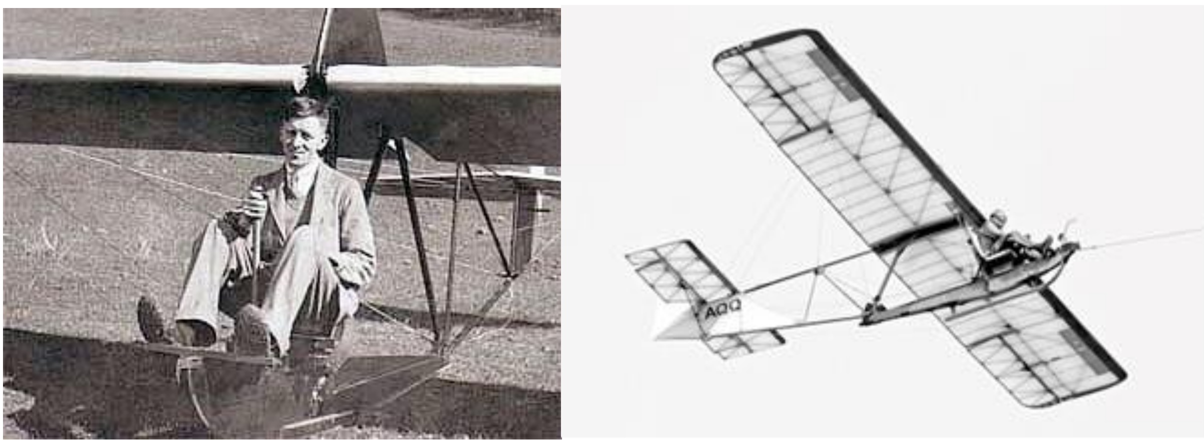
There is an ancillary control I should mention at this point I call the load wheel, and I call it that because it normally is a wheel (sometimes a lever) which can be rolled fore and aft and it takes the fore and aft ‘load’ off the angle of attack control when the angle of attack has to be held constant for any period of time and the physical effort of holding the stick in that position for that period becomes tiring. It simply relocates the no-load position of the stick to wherever the operator wants it to be for his comfort. Its effect can be overridden at any time by the operator moving the stick but it does ‘zero’ the starting point for the airspeed sensing function of the stick.

The Alignment Control.

The alignment control is used to ensure the fore and aft axis of the prosthesis is aligned with the direction it is going (pointing into the relative wind). The control is a horizontal stick on the floor, pivoted at its centre and moved with the operator’s feet. This control is primarily used to enhance or fine tune the aeroplanes ‘natural tendency’ (directional stability) to point into the relative wind. The degree of movement required to achieve its primary purpose can be determined, in an open prosthesis, by the direction of the relative wind on the operators face and if the prosthesis has a ‘windscreen,’ by the angle a short length of string attached to the outside of the windscreen makes to the local vertical when influenced by the airflow over it. If the prosthesis has a front mounted engine and propeller, the propeller slipstream can distort these two direct airflow sensors so an internally mounted alignment ‘ball’ can provide the same information, undistorted. (Some aircraft have a load wheel on the alignment control too.)



Control Sticks and Wheel



Flight Prosthesis with only Two Sticks

Okay, so the angle of attack control stick and the alignment control stick enable the operator the freedom to manoeuvre at will in three dimensions in the sky with, literally, a flick of the wrist and the tap of a toe; but what about all that other stuff in the cockpit? Read on.

Thrust

To move our prosthesis through the air some form of thrusting force is required to overcome the resistance of the air to our motion. Gliders use a downhill component of gravity to do this; similar to a bicycle rolling downhill, but all other aircraft utilize some type of engine coupled to a ‘power to thrust’ converter of some type. A propeller is the most common type of converter used on light aircraft. The thrust is controlled by one or two levers operated by the hand not occupied with control of the angle of attack. Move the levers forward for more thrust and back for less. Much simpler than a bicycle with 12 gear ratios.

Gauges

Our prosthesis can be equipped with a few instruments and gauges to assist the operator. They should be mounted predominately and in this order of priority, they are:

1. An alignment ball, to assist the operator in more accurately keeping the aircraft pointing where it is going.

2. A lift meter, to assist the operator’s seat of the pants sense in determining more accurately the centripetal force caused by the wings and imposed on the rest of the aircraft at various speeds and angles of attack.

3. An airspeed indicator, to assist the operators stick pressure sense to more accurately assess the aircrafts airspeed.

4. A power meter of some sort, tachometer, MAP gauge etc; to enable the operator to set predetermined power/thrust settings.

5. A height meter. This devise indicates the height above an adjustable air pressure datum.

6. An orientation meter. This devise is of use if the operator is concerned with his orientation relative magnetic north.

7. There are a bunch of other gauges which often pre-occupy aviators too much, such as engine condition gauges, fuel gauges, ammeters and rate of turn indicators; these need only be referred to occasionally depending upon circumstances.

8. What about an angle of attack indicator? You already have one in your hand and that is all that you need. If you know where your hand is you know what your angle of attack is.

Lift Meter, Alignment Ball & Orientation Gauge setup in my Aeroplane

I am sure that by now you have retranslated my new names for these controls back to those by which they are commonly known, but with new insight into their primary function; and if you have understood the dynamics and aerodynamics I have taught you in book one you will understand that everything you have learned about how aeroplanes fly and manoeuvre has its roots in the actions and effects of the two very simple controls I have called ‘sticks’. **What you do with them causes the most fundamental aerodynamic effects from which all other effects emanate, and this is so in all aeroplanes regardless of their size or technical complexity**.

Regardless of Size or Complexity

So! Your aeroplane is your flight prosthesis. You strap it onto your backside and you connect your brain to the wings via your arm and hand and the control stick, and through the stick you can connect your senses to ‘feel’ the angle of attack and the airspeed giving you the freedom to manoeuvre at will in three dimensions in the sky. With practice the use of these controls will become as easy and unconscious as walking, and the prosthetic wings will simply become *your wings,* and with them you will fly …. Just like a bird!

It’s all in how you think about it.

Lesson Eight

Introduction to Maneuvering at Constant Angle of Attack

First I will start with a disclaimer. As I have indicated in those relevant lessons of Book One, the stick position/angle of attack relationship is influenced by the Centre of Gravity position, Flap Setting and Ground Effect. However, during the course of most of your flying in a light aeroplane you will not be flying in ground effect (unless you are an agricultural pilot), you will not have the flaps down during these manoeuvres, and the centre of gravity will not have moved around too much from one flight to the next. So I am going to ignore the small variations caused by these three influences.

So how do we apply the constant angle of attack principle to our everyday flying? If you are interested in the art of aerobatics, the principle underlies every pitching manoeuvre you will perform, and I will be discussing its applicability to aerobatic manoeuvres in future lessons in. For now, for non-aerobatic pilots, I will restrict myself to describing a manoeuvre that ‘normal category’ aeroplanes can perform and explain how to do it smoothly and safely in order to explore this principle. I will describe additional manoeuvres which also use this principle, and are applicable to non-aerobatic aeroplanes, in the next few lessons.

We have already learned from Book One - Lesson Seven, ‘Manoeuvring’, the way in which an aeroplane can be ‘diverted’ from a straight flight path. It involves the application of excess lift in the direction we wish to manoeuvre or turn, to create a centripetal force. This excess lift is generated by increasing the angle of attack beyond that required for straight and level flight at that speed, and by pointing it in the direction we wish to turn by banking the aeroplane.

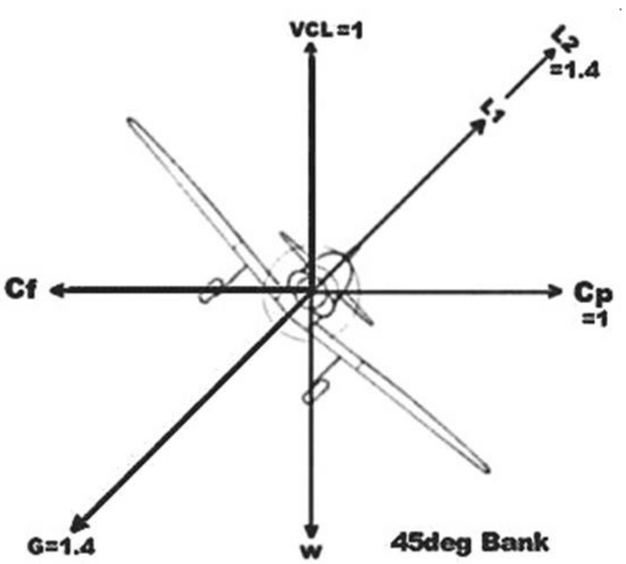


Figure One

A level turn involves rolling to the desired bank angle and easing back on the stick to increase the angle of attack to generate the correct amount of lift to both balance the weight, with the vertical component of lift (VCL), and create the centripetal (turning) force. Figure One is a repeat of the Book One - Lesson Seven diagram showing all of these forces, their components and resultants in a balanced, level, 45º bank turn.

So what would happen if, having established this 45º banked turn, we increase bank to 60º but don't increase the angle of attack any further (or reduce it)?

If we 'over bank' in this way, the vertical component of lift (VCL) will now be insufficient to balance the weight (as shown in Figure 2a), the attitude will go down, the aeroplane will start to descend and the airspeed will start to increase. Also the horizontal component of the lift force (Cp) will be greater, so the aeroplane will begin to turn a little tighter. This is possibly a steeper descending turn than you have done before, but fear not, if we do not move the stick fore or aft, that is, if we hold the angle of attack constant, the lift will increase as the square of the airspeed increase, and will cause the aeroplane to level off again as the vertical component increases and causes the attitude to pitch up to the level turn attitude (as shown in Figure 2b). At that point the vertical component of the lift will, once again, balance the weight. The airspeed will have increased about 20% during this simple exercise.

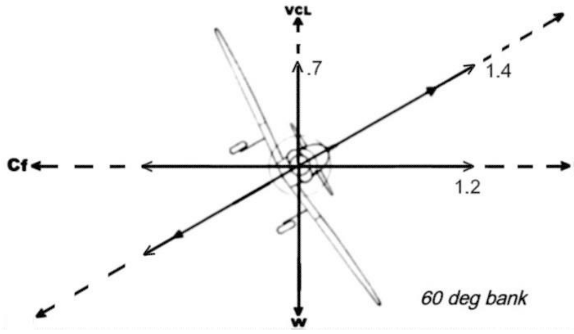


Figure 2a Over bank, VCL=0.7

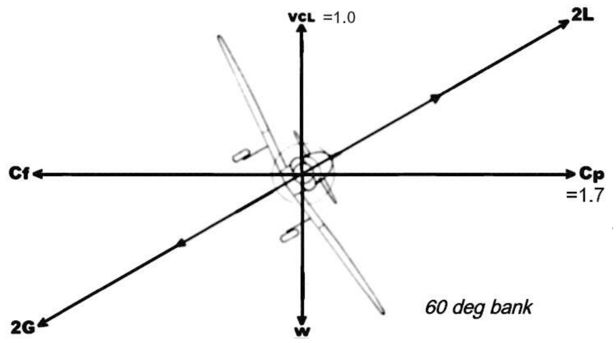


Figure 2b Airspeed increase, VCL=1

Once the aeroplane has returned to a level turn it will begin to slow down, lose lift and return to a descent, unless the bank angle is smoothly reduced to 45º as the aeroplane slows, thus returning the aeroplane to its original level turn.

Try it, and during this simple manoeuvre you will note that the force required to hold the stick position (A/A) will increase as the airspeed increases and decrease as the aeroplane slows. It's a bit like 'arm wrestling' someone with the aim of not letting their arm move as they vary the force they apply. You will also note that the 'G' you experience will increase from 1.4G to 2.0G, and then decrease again. This change will be very smooth. This is because the 'G' will be varying as the equal and opposite reaction to the lift force, and the lift force is **<u>only</u>** varying with the airspeed because you are holding a constant angle of attack.

So what is the purpose of this little exercise? What have we learned? We have learned that by holding a constant stick position the change in 'G' is very smooth throughout the manoeuvre and the initial back pressure we needed to exert on the stick varies with the airspeed. We have learned how to manoeuvre the aeroplane very smoothly at constant angle of attack and we have learned to 'feel' the airspeed changes through the stick. So now the stick not only gives us a direct feel of our angle of attack but also a feel for our relative airspeed!

After you have repeated this exercise a number of times to get used to the cyclic variation of stick force and 'G', you can 'ramp up' the manoeuvre by reducing bank angle to less than 45º, say 30º, whilst holding the angle of attack (stick position) as the aeroplane starts to level off at the bottom of the manoeuvre. This will cause the attitude to pitch up into quite a 'nose high' climbing turn because the vertical component of lift will now be well in excess of that required at 30º of bank, as shown in Figure 3.

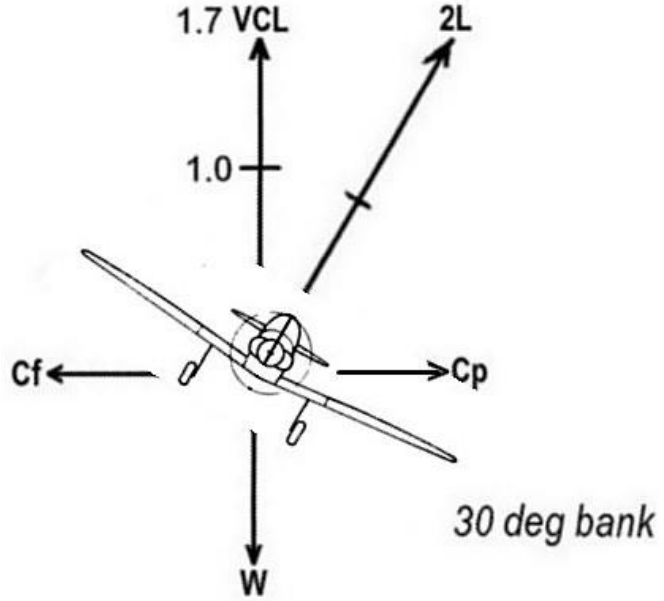


Figure 3. 2L & 30º under bank

As the aeroplane approaches the top of the manoeuvre it will have slowed to about 20% less than the initial airspeed, the lift will have progressively reduced and the stick will have become 'lighter' in your hand. The aeroplane will then start to curve over into a descending turn, and, as the attitude passes the level attitude, smoothly increase bank again to 60º, letting the nose fall and the aeroplane accelerate into a 2G turn again. You can repeat the whole manoeuvre, oscillating between 30º and 60º of bank, again and again, and as long as you hold a constant stick position throughout the manoeuvre(s) the aeroplane will fly them at constant angle of attack and the stick forces and the 'G' will vary smoothly. Even though you will have a low airspeed and a moderate bank angle at the top of the manoeuvre you will not (cannot) stall because you have not moved the stick back and increased the angle of attack to the stall angle. You will, however, need to adjust the lateral (aileron) control slightly to counter any tendency for the aeroplane to 'roll on bank' during the manoeuvre for those reasons explained in Book One - Lesson Seven, 'Manoeuvring'.

In order for the airspeed sensing aspect of this exercise to work for you, you need to leave the elevator trim control alone. Set it for straight and level cruise speed, and leave it there. The trim control is designed to help maintain a particular tail plane angle of attack and therefore a particular wing angle of attack. It is one of the three variables which affect the force you have to exert on the stick at any particular phase of flight. Let me explain. A force will be required on the stick to maintain straight and level flight if the aeroplane is 'out of trim'. This is the first variable. Then, when we enter a turn and move the stick back to increase the angle of attack the appropriate amount, a steady force will be required to hold this new stick position. This is the second variable. Finally, if the airspeed changes, this force will have to change a corresponding amount in order to hold the same stick position. This is the third variable.

Earlier I used the term 'relative airspeed'; what I mean by that is that the stick force changes that you will feel through the stick as the airspeed changes (the third variable) are relative to the stick force required at a steady airspeed at that angle of attack. The airspeed and angle of attack at which the aeroplane was initially trimmed to fly 'hands off' is the datum from which you will feel these subsequent stick force changes. Set the trim the same way each time you fly to fix this 'first variable' and you will quickly gain a 'feel' for the changing 'relative airspeed' of your aeroplane as the stick force required to hold a constant angle of attack changes throughout the manoeuvre.

If you feel that the bank angles I have suggested in this chapter and the attitudes which result from this exercise are a bit too extreme for your comfort then try just oscillating between 30º and 45º to begin with and slowly build the bank angles and attitudes as you gain more confidence, but remember, hold the angle of attack throughout.

Lesson Nine

2G Turn

Normal category aeroplanes are somewhat limited in the number of manoeuvres that can be performed in them. Most pilots trained in modern flying schools are taught to restrict their manoeuvres even more. Climbing, descending, gentle and medium banked turns are about all that the average student pilot is trained to do these days.

However, the manufacturers of these aeroplanes often list additional types of manoeuvres that can be performed. The aircraft's flight manual lists them and they are often mentioned on a placard in the cockpit. Those seen in American manufactured aeroplanes are, 'Steep Turns', 'Lazy Eights' and 'Chandelles'. Many pilots have, over the years, attempted these manoeuvres without knowing exactly what they are or how to perform them safely. The end result is often a 'bent' aeroplane or worse!

Fortunately each of these manoeuvres is amenable to the use of the 'constant angle of attack technique' I detailed in the previous lesson, so I am going to explain what they are and how to perform them smoothly and safely using this technique in this and the following lessons.

The first manoeuvre I will discuss is the 'Steep Turn'. Let me first define the term 'Steep Turn'. The 'steepness', or otherwise, of a turn is merely a subjective statement of the angle of bank used in a particular turn. Most flying schools which use touring aeroplanes as training aeroplanes suggest that an angle of bank of 45º is a 'steep' turn. This is possibly because the high wing or solid roof of the aeroplane obscures the area into which the aircraft is turning at these angles of bank. Pilots of aircraft with better 'in turn' visibility often only regard 45º as a medium bank angle and call 60º of bank a steep turn, hence the subjectivity. A turn of 60º bank utilizing the constant angle of attack principle, I call a '2G turn', for reasons which will become apparent shortly.

Now in order to make a level turn at 2G the aircraft has to be banked to 60º. I repeat below the vector diagram that I have used in previous lessons to refresh you on why this is so. Remember, the vertical component of lift (VCL) is the force opposing the weight (W). See Figure One.

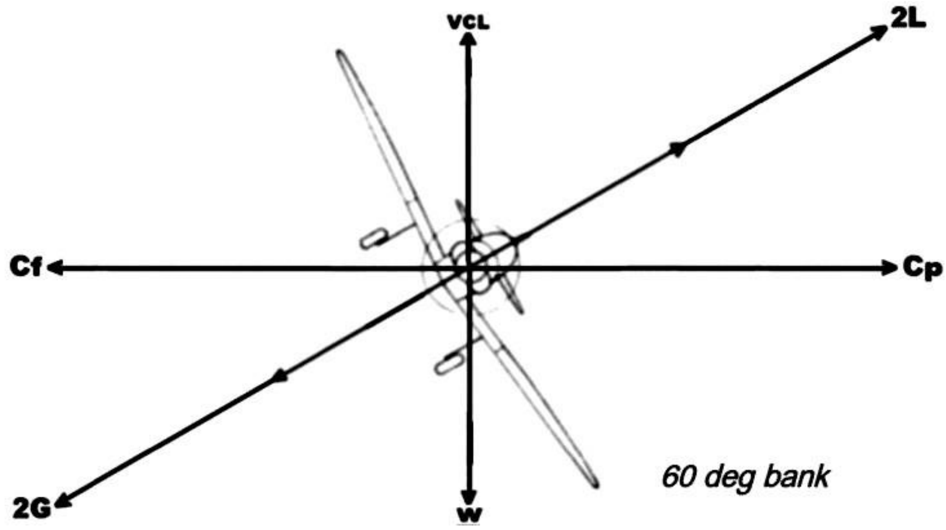


Figure One: 60º banked turn at 2G

So when I use the term '2G turn', am I really just talking about a 60º banked turn and simply renaming it? Yes and No! Sure we start out by entering a 60º banked turn the normal way, but how we control the turn once it is established is different to conventional teaching. I will first explain what I mean by 'conventional teaching' with respect to a gentle turn of 30º of bank.

Figure Two is the vector diagram of the forces involved in a 30º banked turn.

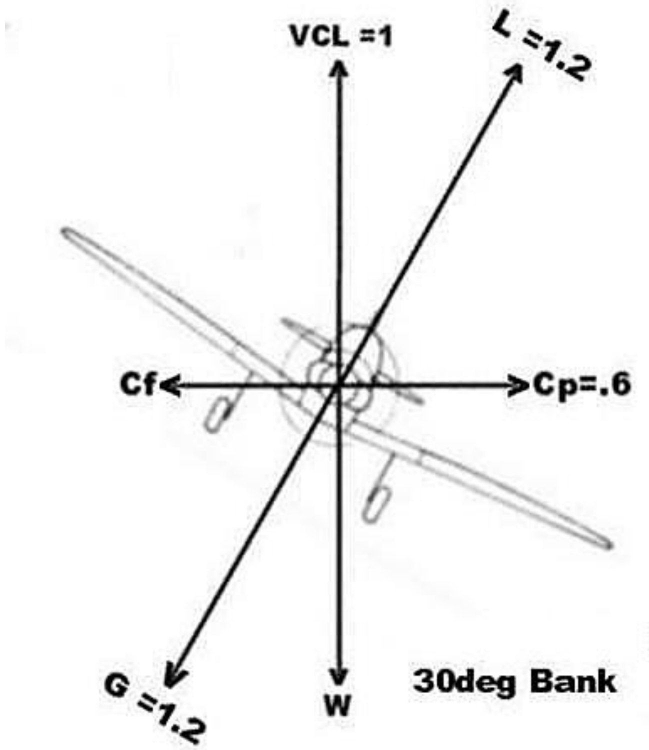


Figure Two: 30º banked level turn.

Once the 30º banked turn has been entered by rolling on the bank and simultaneously increasing the angle of attack (and balancing with rudder), the student pilot is taught to control the attitude and correct for any deviation from level flight by making small angle of attack changes. That is by moving the stick fore and aft to raise or lower the attitude.

For example, imagine that the turning aeroplane is also descending slightly. Easing the stick back will increase the angle of attack which will increase the lift and therefore the vertical component of the lift, thereby raising the nose attitude slightly and causing the aeroplane to return to level flight. (Much the same as we do in straight and level flight.) The following diagram shows the changed forces in a 30º banked turn which will achieve this effect. You will note that there is little difference between the lift increase (L+) and the vertical component increase (VCL+). See Figure Three.

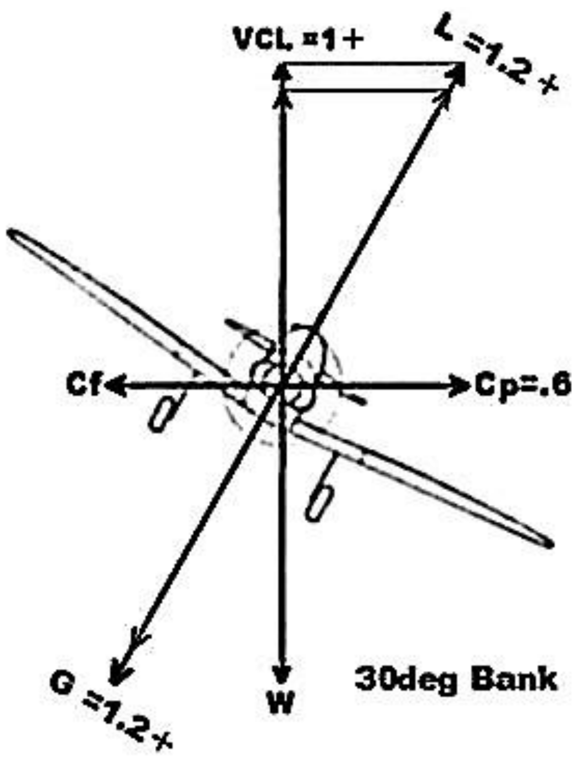


Figure Three: Increased lift and vertical component.

Because the bank angle is low this technique is adequate for adjusting the attitude during the turn. It can be done reasonably smoothly and will not upset the passengers, (G+ is only a slight increase in G). I call it a 'constant bank, variable A/A technique,' and this is what is commonly taught to student pilots.

If, however, this 'conventional' technique is used at 60º bank, a rough ride will result. Examine Figure Four. You can see that to increase the vertical component of lift (by the same amount as previous) to correct the attitude, the lift has to be increased twice as much! This will cause the 'G' experienced by pilot and passengers to vary significantly. It will feel like you are on a roller coaster ride as this extra G comes and goes.

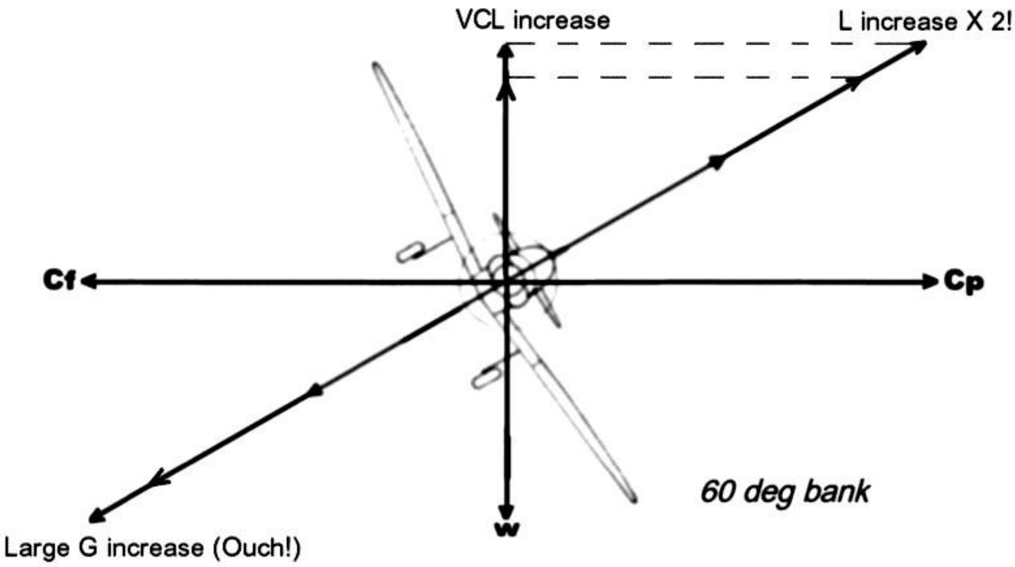


Figure Four: The making of a 'Roller Coaster Ride'

So how do we fly a steep turn without turning it into a roller coaster ride? Once the angle of bank is established and the angle of attack increased to twice what we had in straight flight, that is, 'pull' 2G, lock your arm and hold the angle of attack (stick position). If you note a flight path deviation from level adjust the bank angle slightly without making any adjustment to the angle of attack (stick position). This will vary the vertical component of lift directly whilst maintaining 2L & 2G. In the following diagram you can see that the vertical component has been increased by reducing the bank slightly. See Figure Five.

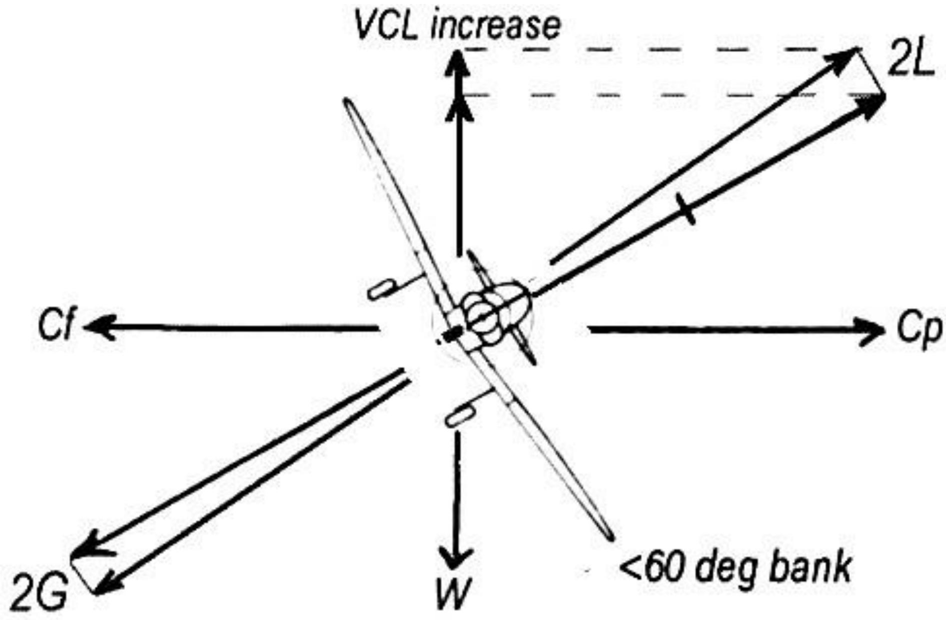


Figure Five: Increased VCL with Constant A/A and constant 2L & 2G.

Of course the reverse would apply, that is we increase bank slightly, if the vertical component had to be reduced as shown in Figure Six.

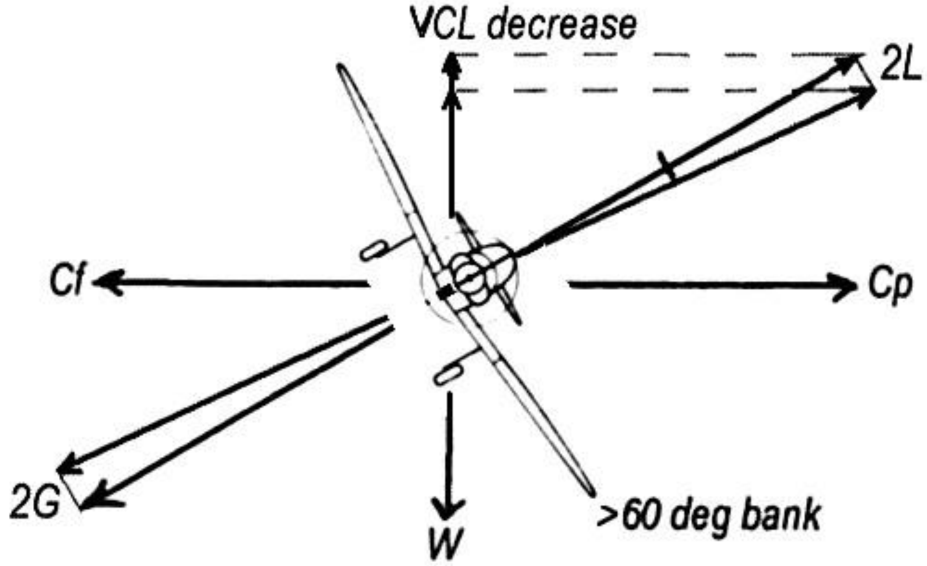


Figure Six: Decreased VCL with Constant A/A and constant 2L & 2G.

I must emphasize that only small bank angle corrections are necessary, 2º to 3º will be enough for most corrections if you detect the attitude change quickly. (The angles in the foregoing diagrams have been exaggerated for clarity.) In this technique we maintain the angle of attack, lift and G, and vary the bank angle to correct the attitude, so I call it a 'constant A/A variable bank' technique. Ultimately you may stabilize the turn at 58º of bank or 61º of bank, who could tell? Who is going to care if it is not exactly 60º? The corrections you make will be subtle and smooth and by any subjective definition it will still be a steep turn.

How do we detect small attitude variations quickly and then 'fine tune' the final attitude? We use an attitude reference point (ARP) on the windscreen. See Figure Seven.

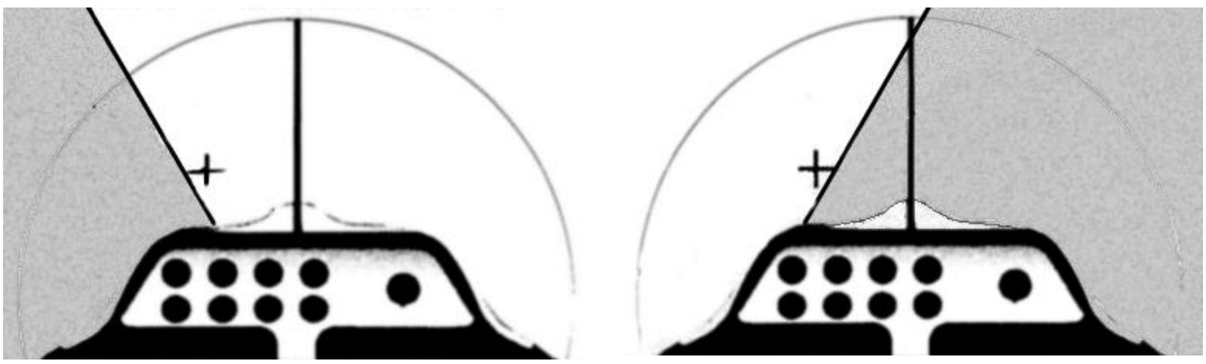
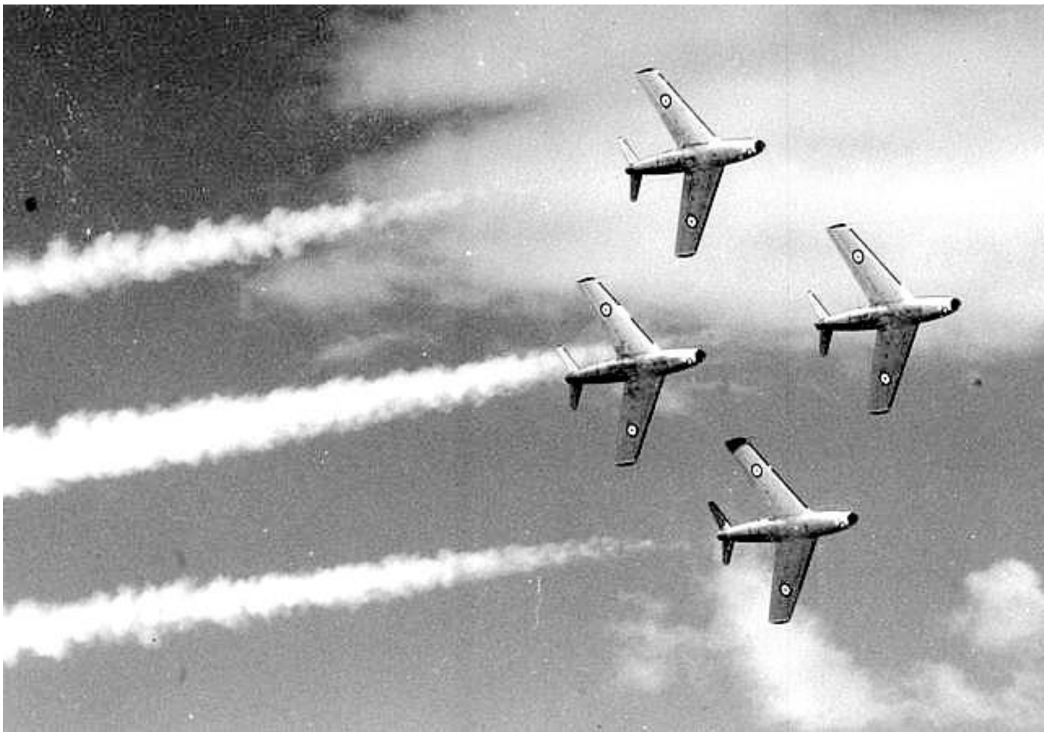


Figure Seven: The ARP position in 2G turns Left and Right.

Because of the increased angle of attack and G during the turn, the ARP will have to be positioned a little above the horizon. (Remember the ‘Eyeball Sag’ from Lesson One.) You will have to experiment with this ARP positioning a few times to establish an attitude which works in your aeroplane. (Use the altimeter as your reference instrument because the VSI has too much lag to be useful in this dynamic situation.) Once set, any variation of this attitude will become apparent before its effect is registered on any of the instruments, and can be quickly corrected before it is registered.

Don’t forget that in a 2G turn the total drag has doubled (approximately), so you will need to apply power to sustain your airspeed. (Book One - Lesson Seven ‘Manoeuvring’.) Most light GA training aeroplanes in the less than 200HP class will not sustain cruise speed in a 2G turn, so despite applying maximum continuous power the speed will reduce about 10% of cruise speed. This speed reduction does not alter the technique I have just described, but does contribute to the attitude adjustment required to maintain level flight. (Figure Seven.)

Once you have the 2G turn ARP attitude figured out, and once you can hold a constant stick position whilst making subtle adjustments to the bank angle, the aeroplane will turn like it is ‘on rails’! A fellow pilot, sitting next to you, unaware of the technique you are using and without an ARP on his side of the windscreen will not be able to detect the subtlety of your flying, but he will be impressed by its accuracy and smoothness, especially when you keep ‘eating’ your own wash after 360º and saying, “Damn! I hate it when that keeps happening.”



Turning like you are on rails.

Lesson Ten

Lazy Eight

The second manoeuvre on the list is the ‘Lazy Eight’. I have, over the years, heard many pilots confuse this with an aerobatic manoeuvre called a ‘Cuban Eight’. So let me be very clear at the outset. A Lazy Eight is not an aerobatic manoeuvre. The aircraft does not follow a figure eight flight path through the sky in the vertical plane as it does in a ‘Cuban Eight’, The actual flight path through the air is depicted in the following ‘outside’ view of a Lazy Eight.

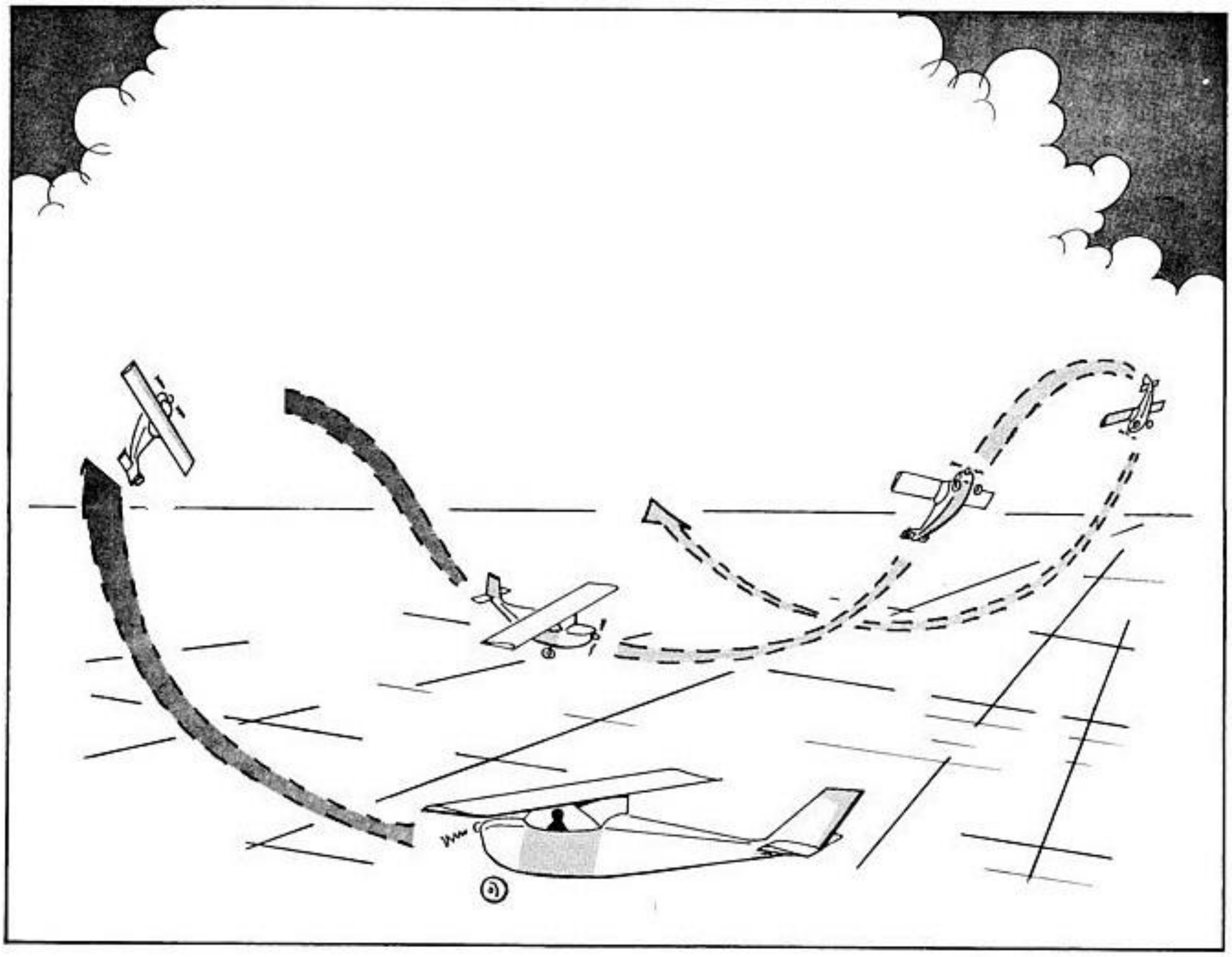


Figure One

You can see from this diagram that an aeroplane performing a Lazy Eight actually follows an ‘S turn’ path over the ground; it is the nose (ARP) attitude of the aircraft that traces a horizontal eight across the sky and the earth with the horizon as the primary axis. Figure Two depicts this ‘tracing’ of a figure eight, showing the aeroplane’s attitude viewed from the rear.

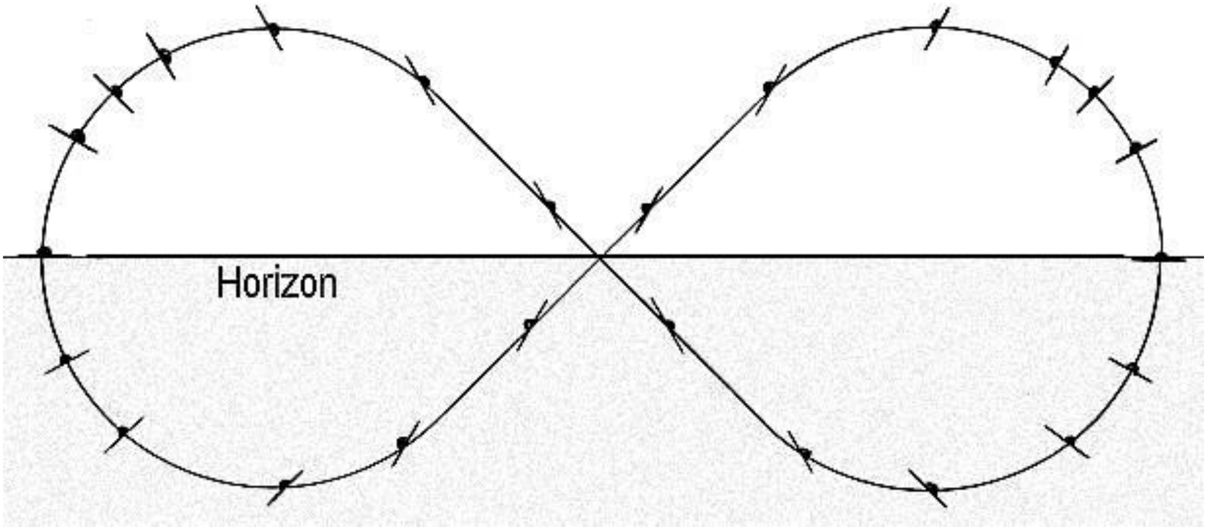


Figure Two

The Lazy Eight can be subdivided into two manoeuvres linked together called 'Wing Overs', the first done to the right followed by one to the left (or vice versa). A 'Wing Over' is a variation of the manoeuvre I detailed in lesson six, and employs the same constant angle of attack principle. So I will first concentrate the discussion on how to fly a 'Wing Over'.

First, fly a few 45º banked turns to recalibrate your backside to what 1.4G feels like and what the stick position is to achieve the angle of attack to fly this turn. Then, starting from straight and level flight at cruising speed, apply full power and smoothly but positively, pull the stick back to this position, that is, pull 1.4G. The ARP will start to pitch up quite rapidly, so once the angle of attack is set, lock your arm and hold it whilst smoothly rolling the aircraft to 45º of bank. Now this is not the same as rolling into a 45º banked turn because we have set the angle of attack before rolling. The ARP will be passing the climb attitude as we initiate the roll and will then get higher as the roll continues. The attitude the ARP follows to this point is shown in Figure Three, (rolling right).

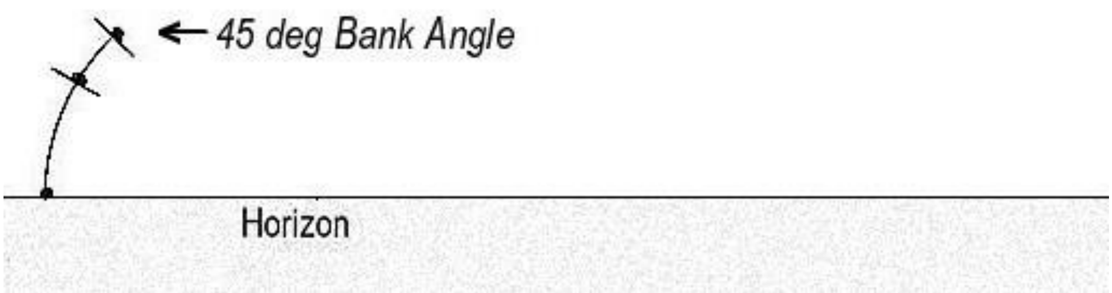


Figure Three

The rate at which you roll will determine how high the ARP gets. Rolling slowly will produce a very high attitude whilst rolling too quickly will cause a flat attitude. Somewhere in between, using about half aileron deflection will produce the 'Goldilocks' attitude. See Figure Four.

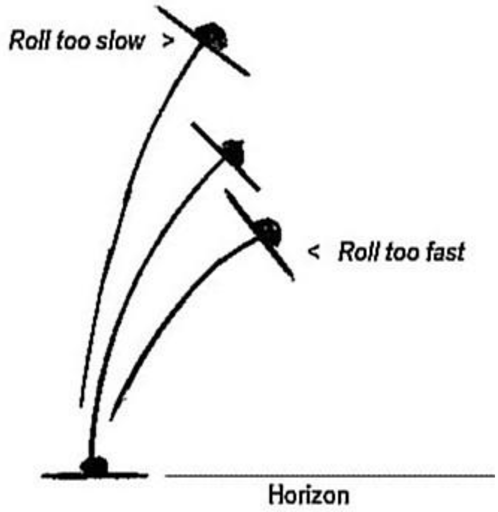


Figure Four

Experimenting with the roll rate (whilst holding the angle of attack) will produce an attitude that you will be comfortable with.

Once the bank has reached 45º centralize the aileron input and keep holding the angle of attack. As the aeroplane slows the lift and its vertical component will decrease and the attitude will start to fall whilst the turn continues. During this part of the manoeuvre the bank angle will increase of its own accord to about 60º because of the different airspeeds of each wing. This will help sustain the turning component of the decreasing lift but accelerate the reduction of the vertical component. Let it happen, but peg the bank angle at 60º with a touch of opposite aileron. The ARP will arrive back at the horizon with this 60º of bank set, and the aeroplane will have turned through about 60º of heading change. See Figure Five.

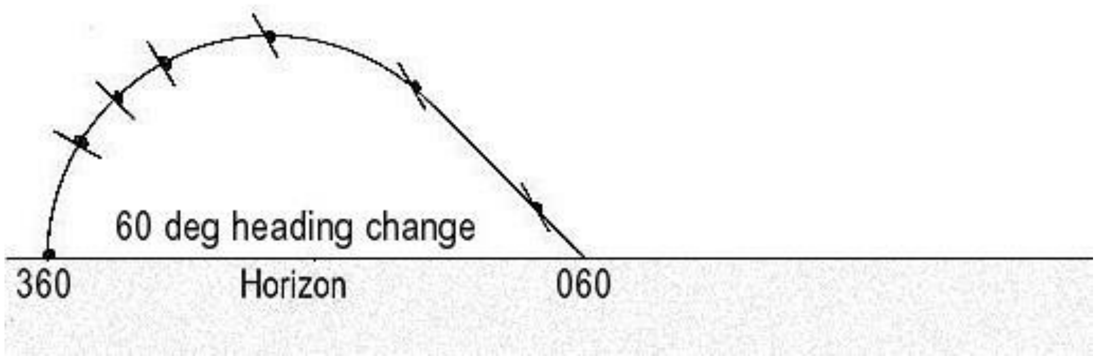


Figure Five

Hold the angle of attack and the bank angle until the ARP has dropped about 10 to 15º below the horizon. At this point commence rolling the wings back to a level attitude whilst holding the angle of attack. Apply enough aileron input to roll out at the same rate as the initial roll into the manoeuvre. Continue using full power. See Figure Six.

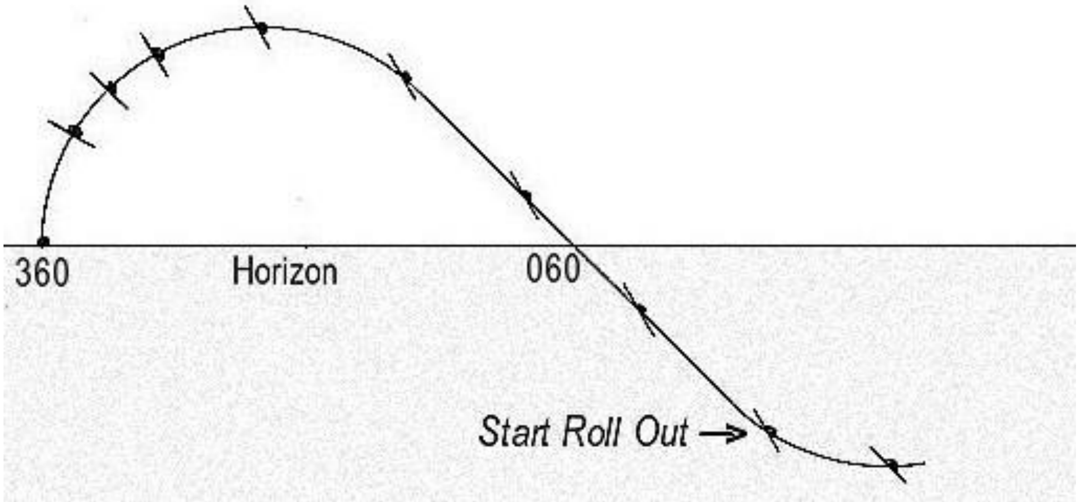


Figure Six

As the aeroplane accelerates ‘down hill’ the stick force will increase, so ‘arm wrestle’ it to maintain the angle of attack. As the speed builds, the lift will increase, and because the angle of bank is reducing, the vertical component of lift will increase rapidly and the nose will quickly pitch back to the level attitude. The aim is to arrive with the ARP on the horizon with the wings level. You may need to adjust the roll rate slightly during the last part of the manoeuvre to achieve this. Figure Seven shows the roll out and final attitude to finish the manoeuvre.

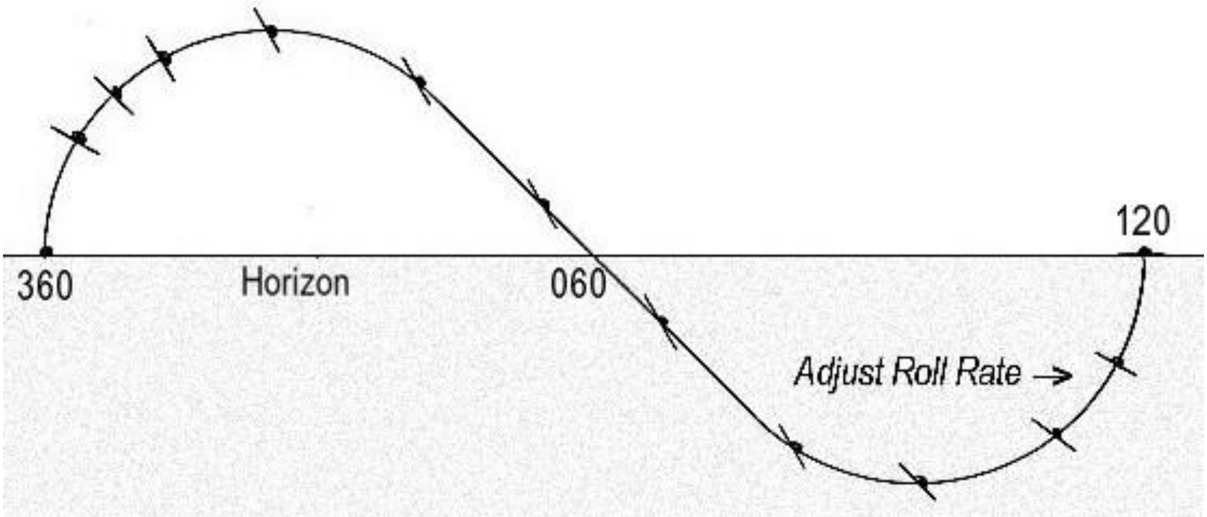


Figure Seven.

The aeroplane will arrive back at the straight and level attitude after a further 60º of heading change, or a total heading change of 120º, at the same altitude and airspeed it had at the beginning of the manoeuvre.

Now a few notes of caution: First, DO hold the angle of attack constant throughout this manoeuvre. As the aircraft slows the stick force will decrease making it easier to pull further back, DON’T! You could possibly reach the critical angle of attack and stall the wing. If this happens it will most likely be an asymmetric stall which could initiate an autorotation! Second, as the aeroplane accelerates in the second half of the manoeuvre be ready to lock your arm and not let the angle of attack reduce, otherwise the aeroplane will arrive wings level in a dive, losing altitude unnecessarily, and, with fixed pitch propellers, requiring a power reduction to prevent an RPM over speed.

The Wing Over is a manoeuvre that involves ‘rolling G’; although not enough to ‘test’ the boundaries of the manoeuvre envelope if it has been flown correctly. If you have forgotten the concept of rolling G, go back to Book One - Lesson Thirteen and read it again. If you realize you have inadvertently relaxed the angle of attack as the aeroplane accelerates in the second half of the manoeuvre and have allowed the airspeed to build up more than normal, be very cautious about reapplying the angle of attack and increasing the roll rate to get back to where you should have been at this increased airspeed, as this could bring a normal category aeroplane close to its rolling G limits. Better to treat the situation as a spiral dive recovery, that is: reduce power, relax the angle of attack, roll to wings level, and then pull to a level attitude.

Similarly, if you delay the roll-out until the nose is much lower than recommended you may, once again, ‘test’ the boundaries of the aircraft’s rolling G limit, because the speed will become higher than planned. If you have delayed the start of the roll out, recover as per the spiral dive recovery.

Okay, so back to the Lazy Eight. You can see that when we arrive back at the straight and level attitude at the end of the Wing Over we have a choice of releasing the angle of attack to hold that attitude or holding the angle of attack and ‘flowing’ straight into another Wing Over in the opposite direction. At the completion of the second Wing Over the ARP will have traced a horizontal eight about the horizon as shown in Figure Two, and you will have flown a very smooth Lazy Eight, utilizing the ‘constant angle of attack principle’. If flown accurately and consistently you will arrive back on the original heading at the same altitude and airspeed. I recommend using a long straight line feature on the ground as a reference line, to assist you in assessing the quality of your flying.

A question which may have popped into your mind is; “what do I do with the rudder?” You use the rudder for its primary purpose, to balance the aeroplane. You will need subtle use of the rudder to keep the balance ball in the middle throughout the manoeuvre because the aeroplane will be a little more prone to aileron drag when rolling at the higher angle of attack, and the effect of the propeller slipstream will vary with the changing airspeed.

Flying the Lazy Eight is an excellent coordination exercise as well as a manoeuvre which consolidates your understanding and feel of the constant angle attack principal. It will ultimately improve your flying skill and your confidence in the air leading to greater enjoyment of the art of flying.

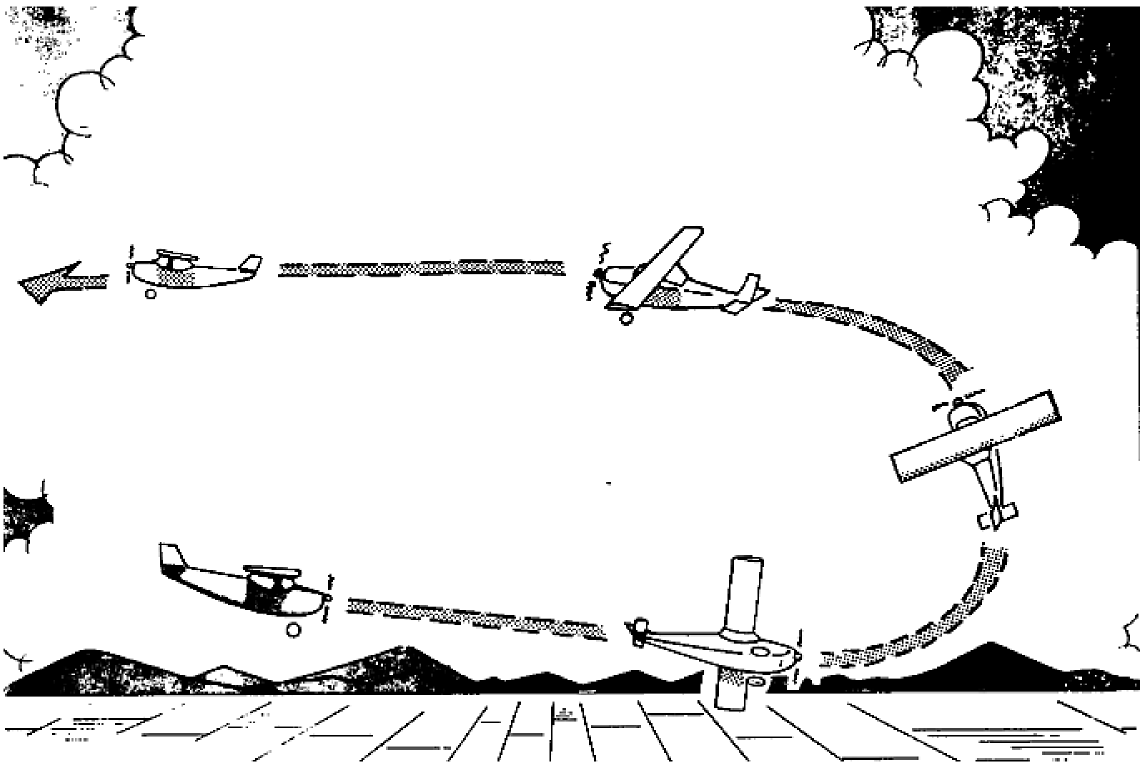
Lesson Eleven

Chandelle

The ‘Chandelle’ is the last manoeuvre on the list. The name ‘Chandelle’ is French for ‘Candle’ which, as we know, is a narrow column of wax which points straight up. Now pointing straight up is NOT what we do with the aeroplane in this manoeuvre. There is an aerobatic manoeuvre in which we do point the aeroplane straight up and it is known nowadays, in English and European countries, as a ‘Stall Turn’, and in the Americas as a ‘Hammerhead Turn’. The original Chandelle manoeuvre was straight up and down, but the name became confused by its use for a completely different manoeuvre, particularly in the USA, so even the French now call their ‘Chandelle’ a ‘Stall Turn’.

Why the history lesson? To show you that aviation is peppered with catchy names for manoeuvres which may differ from one country to the next and often mislead a new pilot into thinking they are something they are not. A perfect example of this is the aforementioned ‘Stall Turn’; the last thing you do in a stall turn is stall! Indeed throughout most of this manoeuvre the angle of attack is as far from the critical angle of attack as you can get! How else could you fly an aeroplane vertically? But I digress - more about this in my book on aerobatics.

So what is the manoeuvre that is now called a ‘Chandelle’? Well, it is a pretty innocuous manoeuvre; it’s a climbing turn at reducing airspeed, and looks something like this:



In my 22 years teaching flying and aerobatics I never bothered with the manoeuvre too much in aerobatic category aeroplanes, but I believe it is in the pilot training curriculum in the USA and, as I said before, it is in the flight manual of many normal category aeroplanes. So before you go out and try an original 'French Chandelle' ('Stall Turn') in a normal category aeroplane and rip its wings off, I guess I should discuss the 'Modern Chandelle'.

The following is an extract from an American flight training manual:

> *"A chandelle is maximum performance climbing turn beginning from straight and level flight and ending at the completion of a 180º turn in a wings level and nose high attitude at the minimum controllable airspeed."*

The term "maximum performance…turn" is somewhat misleading and obviously doesn't mean a maximum rate or minimum radius turn since it involves the conversion of the aircraft's kinetic energy into potential energy during the turn.

Now the most obvious way to dissipate kinetic energy during a turn is to commence a 3.8G level turn with about 75º of bank, and progressively reduce the bank angle to maintain the 'levelness' of the turn as the induced drag erodes the airspeed. (Thereby maintaining the vertical component as the lift reduces.) This would certainly be close to a maximum 'performance' level turn, but I don't think that it would be classed as a Chandelle because we would be dissipating the kinetic energy, not converting it into potential energy by gaining height during the turn. So obviously a 'nose up' attitude and a somewhat reduced bank angle are involved in this manoeuvre.

The 'give away' part of the definition is the attitude and speed configuration at the conclusion of the turn: *"wings level, and nose high attitude at the minimum controllable airspeed."* What will the minimum controllable airspeed be? I suggest 1.1Vs. Note also that the definition does not say that the aircraft has to be in level flight in this configuration as this will depend upon the power output of the engine/propeller. Some powerful aeroplanes will still climb, albeit inefficiently, at 1.1 Vs, which is why I didn't use this manoeuvre very much in my aeroplanes; but a standard trainer of the Cessna 152 class will fly about level at 1.1Vs at full power on the backside of the drag curve.

The first thing you should do is determine what this 'chandelle attitude' and airspeed configuration is in your aeroplane, which shouldn't be too hard. Obviously when flying level on the 'backside' of the drag curve with full power applied the wings will be very close to their critical angle of attack. So to establish the attitude for this configuration in your aircraft, start at a safe height and approach a power off level stall in the normal way, but then progressively reintroduce power as the aeroplane slows to a speed below minimum power speed. (Book One - Lesson Five.) When you have full power applied and the attitude adjusted to maintain an airspeed of 1.1Vs, note this attitude and note the stick position. The stick position will now be very close to the critical angle of attack position, and this will be your 'limit stick position' in the final manoeuvre.

Next, practice achieving this configuration from straight and level cruising flight by setting this 'chandelle attitude' at cruising speed, applying full power, and making some straight ahead climbs. Hold the attitude by progressively increasing the angle of attack to the limit we have set as the airspeed reduces, then hold this angle of attack and allow the aeroplane to settle into the resulting flight path. With powerful aeroplanes it may be necessary to set an initial attitude a little higher than the one we are finally aiming for, and 'zoom' climbing to assist in getting the airspeed onto the backside of the power curve. Once below the minimum power speed, allow the attitude to settle to the final 'chandelle attitude' (by momentarily holding the angle of attack), before continuing to move the stick back to your angle of attack limit, and then allowing the aeroplane to settle into its final flight path. You will note that you will have gained a few hundred feet of altitude during this exercise, thereby satisfying the requirement of converting kinetic energy into potential energy.

I refer you back to the concluding part of Book One - Lesson Eight, 'Climbing', which dealt with 'zoom' climbs. Specifically I want you to note that, in this exercise, when flying a powerful aeroplane, we do not hold the zoom attitude until the aeroplane stalls; we allow the attitude to settle to the 1.1Vs attitude once the airspeed drops below the minimum power speed as I have just described. See Figure One.

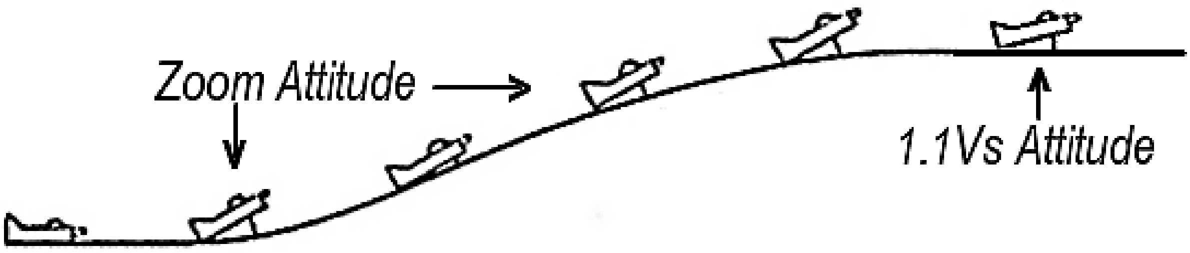


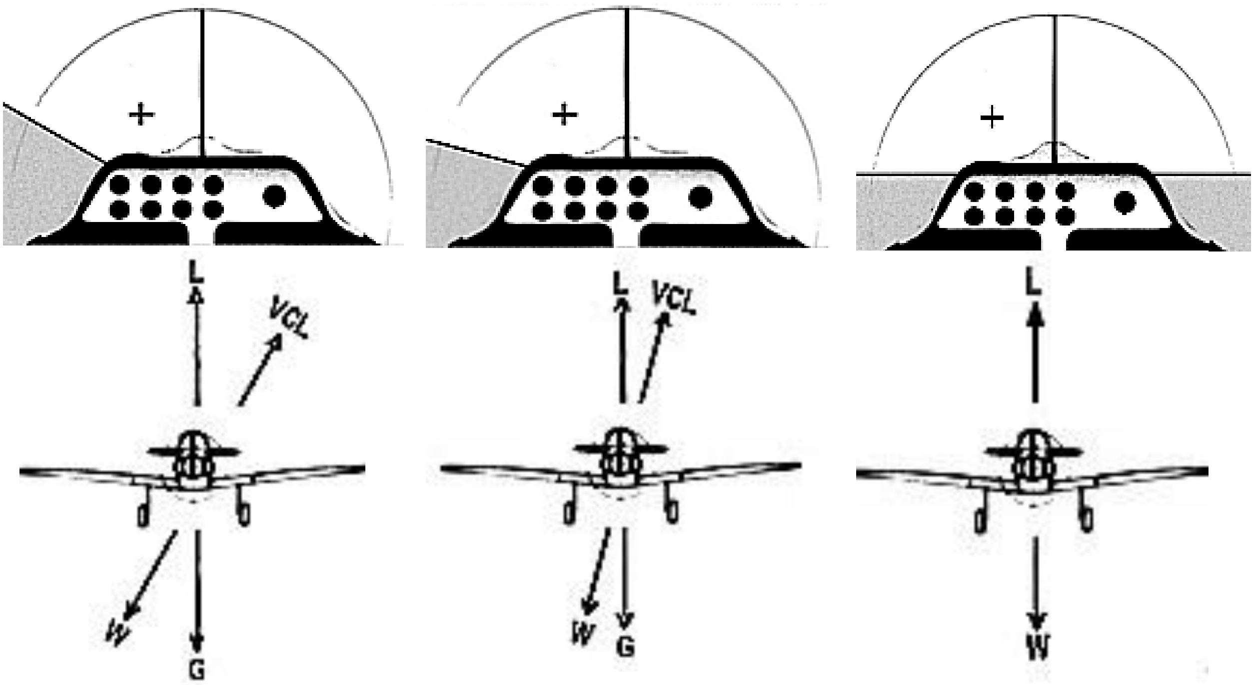
Figure One

Finally, repeat the climb whilst turning with 30° bank. The entry to this manoeuvre will be very similar to the 'wing over' entry described in the previous lesson but not as aggressive. Simply roll to the bank angle as you lift the ARP to the 'chandelle climb' attitude. Hold the bank with a touch of opposite aileron and hold the attitude as the airspeed reduces by increasing the angle of attack until the stick comes back to the previously established angle of attack limit, and then hold that stick position. With the angle of attack fixed the lift will start to reduce as the airspeed continues to reduce and, since the aeroplane is banked, the vertical component of lift (VCL) will start to decrease too. You must now progressively reduce the bank angle to maintain the vertical component as the lift decreases, in order to maintain the attitude. Eventually the wings will be level and you will be in the final configuration again at the limit angle of attack. But on what heading?

The final criterion for the Chandelle is to arrive at the configuration after a 180º turn. Now most pilots would probably focus on this requirement first, to the detriment of attitude and speed control. Leave this till last. Use a long line feature on the ground and fly the manoeuvre I have just described starting in line with this feature and note the final heading relative to this line feature. If you achieve the final configuration short of a 180º turn, fly the manoeuvre again starting with a little more bank. Of course, if you have over turned the line feature try again with slightly less bank. With a little application and practice you will have no difficulty flying the Chandelle through 180º and satisfying all the requirements.

Just as I discussed in the lesson on Lazy Eights, you need to use the rudder to keep the balance ball in the middle throughout this manoeuvre too, because the airspeed is changing and some aileron drag is present.

Here are some key attitude pictures and vector diagrams during a Chandelle.



Initial Attitude. Aircraft slowing. Increase A/A to maintain Lift, VCL and Attitude.

Hold limit A/A. Aircraft slowing. Lift reducing. Roll out to maintain VCL and Attitude.

Final Attitude. Speed Stable at Limit A/A.

Post Script

In this book I have detailed the techniques I teach, and the aerodynamic principles involved in those manoeuvres which can be performed in a normal category aeroplane. The application and practice of these techniques will make you a more confident, smoother, and more accurate pilot. Unfortunately, a normal category aeroplane is too limited to explore other manoeuvres which would have an even greater impact on your flying ability. I am of course speaking about aerobatic flight.

I believe that every student pilot should be taught basic aerobatics as an integral part of their flying training. That is the way I taught flying at the Sydney Aerobatic School, and that is the way every Air Force in the world does it too. Very few civilian flying schools teach aerobatics because they have neither the equipment nor the instructional capability. Those flight schools which do have an aerobatic training capability usually only offer it as an optional course to post graduate students of their basic training ‘programs’, so they miss the value which could be gained by integrating aerobatics with this basic training.

Most people, including most pilots, are only exposed to aerobatics at the occasional air show. What they usually see is a spectacular performance by a very experienced aerobatic flyer in an advanced aerobatic aeroplane at very low level. This is not basic aerobatics, and is far and away more advanced than what I am talking about. Unfortunately many pilots are daunted by this type of flying (and their spouses scared by it), so they push any thought of doing aerobatics from their mind.

The popular press insists upon calling aerobatics “Stunt Flying” which is also a ‘turn off’ for many pilots. I have had many discussions with members of the ‘Press’ about the use of this term and have been challenged to define the difference. My standard response is to compare aerobatic flying to spring board diving. During the Olympic Games we all marvel at the ‘twists’ and ‘pikes’ performed by the divers, without giving any thought to the depth of water into which the dive terminates, because the diving pool is always large enough and deep enough to not be a safety factor. So we don’t call the divers “Stunt Swimmers”. But if they were to perform the same aerial manoeuvres into a bucket of water, that would be a stunt!

Basic aerobatic manoeuvres should be performed high in the sky over a large ‘pool of air’, so the proximity to the ground is also not a safety factor. In this environment, with the right aeroplane and a good aerobatic instructor, aerobatics is the very best way to improve your flying skills with safety. It is also great fun.

Useful Quotes, Formulas and Rules of Thumb

A Synopsis of Book One

The following are useful Quotes, Formulas and ‘Rules of Thumb’ extracted from the lessons of Book One for you to use as quick ‘memory joggers’.

Lesson One - The air in which we fly

The international Standard Atmosphere

The International Standard Atmosphere starts at Sea Level with a temperature of 15ºC (Celsius) and a pressure of 1013.2Hp (Hectopascals) or 29.94 Inches of Mercury in the USA. A cubic foot of air under these conditions weighs 0.0765 lb and has a Density of .002376 ‘Slugs’ per cubic foot. As we climb up into the ‘standard’ atmosphere we will find that for each 30ft of altitude gained the pressure drops 1Hp initially and for every 1000ft of altitude gain the temperature drops 2ºC. This temperature drop per 1000ft is quite uniform up until about 35,000ft but the altitude per 1Hp drop expands a little as we get higher so that at 35,000ft a 1Hp drop equals 50ft altitude gain. What this all means is that at 35,000ft it is damn cold, minus 55ºC to be exact and the pressure is down to about one quarter of the sea level pressure.

Density Altitude

Density Altitude is the air density that exists at a given place expressed as an altitude equivalent on the ISA scale. So regardless of its actual altitude, an aeroplane will perform <u>as if</u> it is at the Density Altitude.

Lesson Two - Lift

The Creation of Lift

Lift comes from deflecting airflow down. Deflecting air down with a wing <u>also</u> causes air pressure differences around the wing, and these air pressure differences are proportional to the amount of airflow deflection and the lift. So the pressure differences do not <u>cause</u> lift they <u>result</u> from it being created by other means! That ‘other means’ is Newton’s Third Law of Motion: ‘Action - Reaction’.

Lift Formula

The aviator has immediate, direct, and very positive control of C_L,, primarily by way of control of the angle of attack of the wing but also in a limited sense its camber when flaps are used. The aviator also has immediate and direct control of the airspeed, so from an aviator's perspective the lift formula could be written in a more usable form as:

$$\mathbf{L \infty A/A \times V^2}$$

Obviously the lift is now only 'proportional' to **A/A** and **V** as the aviator has no way of calculating the actual lift force without knowing the other factors. But there is no need to, he or she already knows how much lift is being developed by the wing, because when the aeroplane is flying level the lift equals its weight, and the lift will vary as a factor of this weight in accordance with this simplified formula when either A/A and/or airspeed are varied. <u>That is all the aviator needs to know</u>.

Movement of Centre of 'Pressure'

The centre of pressure/total reaction doesn't move as the angle of attack of a modern wing section changes through the normal flight range.

Lesson Three – Drag

Zero Lift Drag (ZLD)

Zero lift drag increases as the square of the airspeed.

Lift induced drag (LID)

If we double the angle of attack, the lift component doubles, but the induced drag component increases four times! So Lift Induced Drag varies as the square of the angle of attack.

Minimum Drag Speed

At the minimum drag speed ZLD = LID. The minimum drag speed of your aeroplane is a handy speed to know, because it is the speed where you need minimum thrust to fly straight and level, and it is the speed to glide at for maximum range. It is also the speed to fly at for maximum range under power and is very close to the speed at which you can 'loiter' and conserve fuel.

Lift to Drag Ratio

The optimum lift to drag ratio occurs at the minimum drag speed. Since minimum drag speed varies with weight and manoeuvre loads, the optimum L/D ratio varies in a similar fashion. Rule of Thumb: The speed for best L/D ratio is about 1.4Vs in straight and level flight and 1.4Vsm when manoeuvring.

Aspect Ratio

$$\mathbf{AR = Span^2 \div Wing\ Area}$$

There is a simple relationship between change of aspect ratio and change of Lift Induced Drag, and that is that the LID <u>reduces</u> in direct proportion to the <u>increase</u> in Aspect Ratio.

Calculating A/A at various airspeeds

The following is a simple formula which can be used for calculating the A/A at any airspeed if **Vs** and the critical A/A is known.

$$\mathbf{New\ A/A = Critical\ A/A \times (Vs/Airspeed)^2}$$

Lesson Four – Thrust

Datum for measuring propeller pitch angle

It has become customary to use the section 75% out from the hub when measuring the angles of, or considering the characteristics of propellers.

Induced Airflow

The induced airflow velocity at full power is equal to about 30% of the slipstream velocity.

Constant speed propeller control

The constant speed propeller control in the cockpit is now called the 'Prop Governor Control' or the 'RPM Control', however many pilots (including instructors), still refer to it as the "Pitch Control" and still call high RPM settings "Fine Pitch" and low RPM settings "Coarse Pitch", (indeed some aeroplanes still have their propeller governor control labeled this way!) This is NOT correct and is very confusing for student pilots because in certain flight conditions such as high speed and high RPM settings the blades can in fact have a very coarse pitch.

RPM at Vne

Quite often the never exceed speed (Vne) of an aeroplane fitted with a fixed pitch propeller is predicated upon the speed that will cause the propeller to 'windmill' at the engines 'red line' RPM with the engine completely 'throttled' (closed).

Propeller Effects

So the final situation is that the four propeller 'effects', that is: Slipstream Effect, Asymmetric Blade Effect, Torque Reaction and Gyroscopic Effect, are all 'ganging up on us' when we try to take off in a tail dragger aeroplane! They are all contributing to 'swing on take-off'.

Lesson Five – Power

To calculate the power required to fly at any particular speed use the following formula.

Power required = Drag x Speed

Minimum power speed (Vmp) is <u>slower</u> than the minimum drag speed (Vmd)!

Range

The minimum drag speed is the speed to fly to get the maximum range from a given amount of fuel! (Approximately 1.4Vs)

Endurance

Flying for maximum endurance demands the least power (minimum power speed) and so consumes the least fuel and therefore gives you the maximum time in the air. The Minimum Power Speed (Vmp) is less than the Minimum Drag Speed (Vmd). (Approximately 1.2Vs)

Lesson Six – Stability and Control

Stability

There are two types of stability, Static and Dynamic. Static Stability is the tendency for the aeroplane to return to its former attitude after a disturbance, and Dynamic Stability is the number of oscillations it makes whilst doing it.

We cannot even begin to discuss dynamic stability if the aeroplane is not statically stable in the first place, so dynamic stability does not apply to modern 'fly by wire' jet fighters or many high performance aerobatic aeroplanes.

Roll Axis

When the longitudinal axis is aligned with the aeroplane's flight path it appears to roll around this axis, but in fact it rolls around its flight path. Since the reaction forces which keep the aeroplane aloft and provide the rolling couple come from the aeroplane's reaction with the airflow, it follows that the axis of roll must be that airflow direction, which is of course the reciprocal of the flight path.

The Elevator's Control of A/A

Since the elevators are used to adjust the pitch of the aeroplane, it follows that they must also give the aviator control of the angle of attack of the wing and, therefore, control of the total reaction which results from any change in this angle. The 'tail volume' is fixed by the design of the aeroplane, as is the area of the elevator, so the only thing the aviator can alter is the angle of deflection of the elevator. It follows then, that there is a set relationship between the angular elevator deflection of the elevator and the angle of attack of the wing (the ratio between them depending upon the tail volume and elevator area). Crucially, since both wing and tail are moving through the air at the same speed the airspeed has no effect on this relationship. Only two things can alter the wing/tail angle of attack relationship when flying out of 'ground effect', the position of the centre of gravity and the use of flaps.

Lesson Seven - Manoeuvring

Turning

An aeroplane turns as a result of the horizontal component of the inclined lift vector being made into a centripetal force by the action of its directional stability, augmented slightly (if necessary) by a small amount of rudder. The size of the centripetal force will determine the rate of turn (acceleration).

‘G’

The symbol ‘G’ is used to express multiples of acceleration, ie 2G, 3G etc, but ‘G’ is not the force which causes this acceleration but the acceleration itself! However, the term ‘G’ is often used, inaccurately, to indicate the resultant of the force required to produce the acceleration. The aeroplane and the aviator ‘feel’ this resultant force as an apparent increase in weight and it has become common practice amongst aviators to express this apparent increase as a ‘G Force’, which is not exactly correct as ‘G’ is, as I have said, an expression of acceleration not force, but since its misuse is so common I will go along with this common (mis)usage here.

Accelerometers

I believe that every aeroplane should be fitted with an accelerometer and it should be mounted in a prominent place. Why? Well if you have been following my discussion on Newton’s third law, you will know that the ‘G meter’ is also a LIFT METER! It tells the aviator how much lift the wings are generating as multiples of their straight and level lift, at any time, in any attitude, instantly. Do you think this might be a handy thing to know??

Drag in a Turn

‘Rule of Thumb’ for the pilots of ‘normal’ general aviation type aircraft: “If you double the A/A / Lift / G you will double the total drag at minimum drag speed”. That is, 2G on the meter also means about twice the (1.0G) total drag! This is another good reason for having a ‘G meter’ in the cockpit, but if you don’t then think of it this way; the extra weight you feel in a turn pulling you down into the seat is felt by the aeroplane as extra drag pulling it ‘back’ in the air with the resulting loss of airspeed and lift.

Lesson Eight – Climbing

Best Angle of Climb

The best angle of climb occurs at a speed where there is the greatest **excess thrust** over total drag and is a speed less than the minimum drag speed. It is a speed as slow as is safe above the aeroplanes take-off speed. The ‘pilot’s notes’ of most light aeroplanes will declare a speed to attain the maximum angle of climb as something a little faster than the theoretical ‘best’ in order to give a safe margin of speed above the aeroplanes stalling speed (Vs). This is usually about 1.2Vs, which coincidentally, is very close to the minimum power speed!

Best Rate of Climb

The best rate of climb speed is the speed at which the **excess power** is at a maximum and it should come as no surprise to you to learn that this speed is in the vicinity of the minimum drag speed. The aeroplane's 'pilot's notes' will declare a speed a little faster than this optimum speed (about 1.4Vs), not so much for safety but for engine cooling considerations, after all we will be using full power and flying slowly, so an air cooled engine can begin to suffer from a reduced cooling airflow just when it needs it the most.

Climbing 'Rule of Thumb'

In the absence of advisory pilot's notes, or thrust, power and speed graphs, a simple rule of thumb for best angle and best rate of climb for a light aeroplane is 1.2Vs and 1.4Vs respectively, but keep an eye on the engine temperature.

Drag in a Climbing Turn

Remember, the total drag curve is also the 'thrust required curve' and in any turn the drag increases in proportion to the 'G' (remember my drag in a turn 'rule of thumb'?) So even in a turn of only 30º bank angle the total drag has increased by about 20%, requiring a 20% trade off from the thrust (and power) available to climb. What all this means is that aeroplanes can either turn quickly or climb efficiently, but they cannot do both at the same time. So in order to maintain a reasonable rate of climb in a light training aeroplane, it is common practice to limit the bank angle to about 20º-30º.

Lesson Nine – Gliding

Gliding for Endurance

The speed to glide at for **maximum endurance** (minimum sink) is the **minimum power speed**, **(1.2Vs approx).** At this speed Total Drag comprises 1/3rd ZLD and 2/3rd LID. (Ref Total Drag Graph.)

Gliding for Range

The speed to glide at for **maximum range** (flattest angle) is the **minimum drag speed, (1.4Vs approx).** At this speed Total Drag comprises ½ ZLD and ½ LID.

Gliding for Range in a Moving Air Mass

A simple ‘rule of thumb’ is to increase or decrease airspeed (the appropriate way) by 25% of the speed of motion of the air mass, but never slower than ‘minimum sink speed’. (The speed of motion of the air mass is the same as the wind speed experienced by someone on the ground.)

Gliding Speeds at Differing Weight

A simple ‘rule of thumb’ to estimate the change required in the airspeed to compensate for changes in weight is to adjust the airspeed by a percentage equal to **half** the percentage change in the weight. That is, if the weight is increased by 10% the glide speed should be increased by 5%. Therefore a heavier aircraft must be flown faster than a lighter aircraft. The **glide angle will not be altered** but it will come down the ‘hill’ faster and be in the air for less time so it follows that **weight does affect the endurance of a glide.**

Rate of Descent versus Rate of Turn in a Glide

In general terms it can be said that, “As the bank angle increases the rate of turn increases much faster than the rate of descent”. So with due regard for the increased stall speed which results from a ‘tight’ turn, you don’t have to “pussy foot” around when turning toward a safe landing site. Indeed it is better if you don’t.

Lesson Ten – Ground Effect

An aircraft enters ground effect from a height above the surface equal to its wingspan. It then experiences a progressive reduction of its induced drag, depending upon the position of its wings, as it settles toward the ground. A low wing aeroplanes wing, which is about 20% of its span above the ground at touchdown, will experience a 40% reduction in induced drag, whilst a high wing aeroplanes wing, which is about 40% of its span above the ground, will only experience a 15% reduction.

Ground Effect can also alter the airflow around the tailplane (depending upon its location). This usually takes the form of an altered negative angle of attack due to the altered downwash angle from the wing and this will alter the stick position versus angle of attack relationship a little during the landing, often necessitating slightly more ‘back stick’ to hold the landing attitude.

Lesson Eleven – Stalling

Stick Position at the Stall

Since the stick controls the elevators and the elevators control the angle of attack of the wing, there must be a stick position which corresponds to the critical angle of attack, and every other angle of attack too.

*“**You** have direct control of the angle of attack of the wings of the aeroplane you are flying, at all speeds, and in all attitudes in the air!”*

Cause of the Stall

So what causes a stall? The pilot does, by moving the stick to or beyond the stall stick position. If you have inadvertently stalled the wing how do you un-stall it? Simple; move the stick to a position corresponding to an A/A less than the critical A/A.

I must emphasize one more important thing here and that is that everything I have said relates to **stick position <u>not</u> stick pressure.** The pressure or force you will need to exert on the stick will differ depending upon the airspeed and the elevator trim setting.

*The stick force does not matter: the **stick position** does.*

The effect of weight on the stall speed

As a general rule the greater the weight the greater the stall speed (for a particular aeroplane). There is a very simple formula which can be used for calculating the stall speed at various loads if we express the load as a factor of the maximum all up weight. That is, if the additional load doubles the total weight of the aeroplane its load factor is 2 and so on. Here is the formula:

New stall speed = Vs x √Load Factor (That is, the square root of the load factor)

Or: $$V_s(\text{New}) = V_s\sqrt{\text{Load Factor}}.$$

The effect of manoeuvre loads on the stall speed

When we manoeuvre the aeroplane the acceleration causes the apparent weight to increase dramatically and its effect on the stall speed is significant. The foregoing formula applies to this situation too with the ‘G’ being the load factor.

$$Vsm = Vs\sqrt{G}$$

If you want to avoid the mathematics just remember 10%, 20%, 40% increase in stall speed for 30º, 45º, and 60º bank respectively, whatever aeroplane you are flying, be it a Cessna or a Jumbo Jet!

Symptoms of an impending Stall

So what are the general symptoms of an approaching stall? Let’s just put them ‘in a nut shell’ here:

1. Stick position moving toward the stall stick position.

2. Increasing control and airframe buffet.

3. Maybe an electric warning horn.

4. Finally, with the stick at (or beyond) the stall position, the aircraft departs from the desired flight path.

Where the nose is pointing and what the airspeed is, is irrelevant!

Stall recovery

1. Move the stick to the best L/D A/A position whilst simultaneously applying rudder to stop further yaw.

2. Apply full power whilst simultaneously rolling the wings back to their initial attitude with aileron and centering the ball with rudder.

3. Manoeuvre to avoid obstacles (like the ground!) without moving the stick back to the stall point again.

Lesson Twelve – Side Slipping

The use of Side Slip during a Cross Wind Landing

The maximum sideslip angle which can be generated will determine the maximum drift angle which can be accepted, which means, at touchdown speed, the maximum crosswind component in which the aeroplane can be safely landed using the normal threshold speed. When the cross wind component is greater than about 2/3rd of the published maximum it may be prudent to reduce the drift angle by increasing the threshold speed a little, say 10%, which will assist the aviator by requiring a corresponding reduction in the sideslip angle, thereby making the aeroplane more ‘manageable’. Remember, if we have increased speed by 10% the lift has increased by 20%, so we don’t need the lift augmentation provided by lowering of all of the flap. Reducing the flap setting to ‘the first notch’ would be more appropriate in this situation. Indeed, many aeroplanes handle better in a ‘flapless’ configuration at these speeds in a cross wind.

If the wind is all crosswind and strong and the runway is so short as to require the slowest touchdown speed, then it may be prudent not to land there that day. Come back when the wind has abated.

Misconception: If you stall in a side slip you will enter a spin! WRONG, you can no more spin off a properly ‘set up’ side slipping approach than you can off a properly set up ‘straight’ approach.

Lesson Thirteen – Aircraft Structural Limits

Calculation of Vo

Remember the formula for calculating the stall speed at a particular ‘G’? (From the lesson on stalling)

$$\mathbf{Vsm = Vs\sqrt{G}}$$

Which means that:

$$\mathbf{Vo = Vs\sqrt{G}\ \ limit}$$

Vo does not mean that the aeroplane cannot be maneuvered at greater speeds. It simply means that care should be exercised to ensure that the G limit is not exceeded as the pilot is now ‘working without a safety net’!

Calculation of the Rolling G Limit

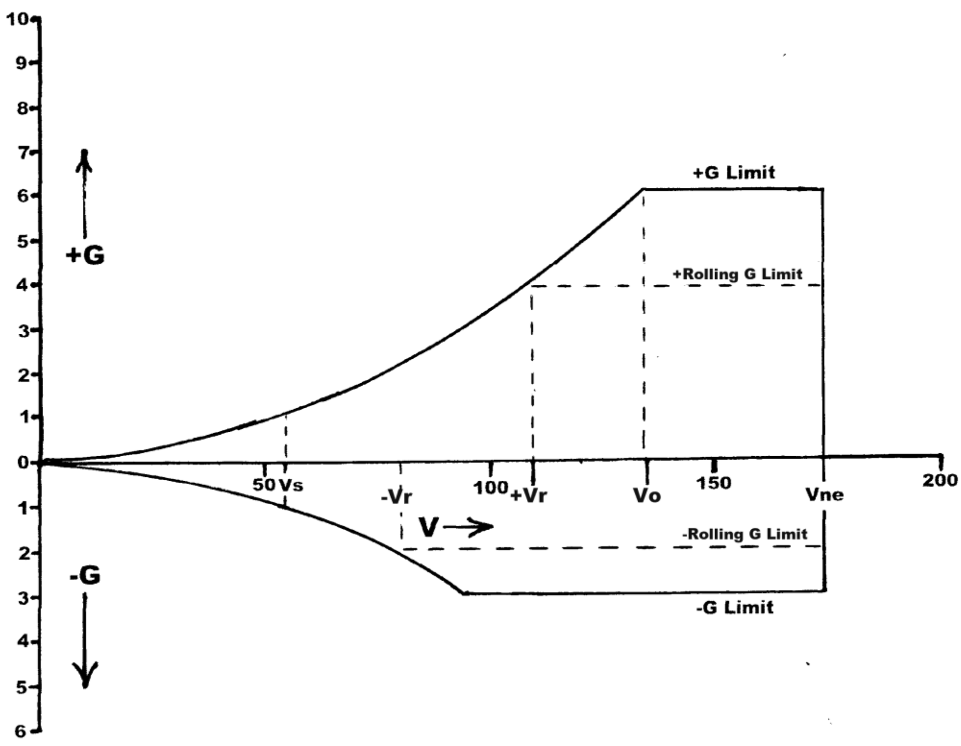
A ‘rule of thumb’ in common use by those aviators that understand the problem (and, now, this includes **you**) is to limit the ‘G’ as seen on the cockpit accelerometer, whilst rolling at maximum rate, to 2/3 of the design limit. That is:

Rolling ‘G’ limit = 2/3 Symmetrical ‘G’ limit.

Can an aeroplane be rolled at all above its rolling G limit? Yes it can, indeed at its rolling G limit it can be rolled at maximum rate but the roll rate must be progressively reduced as the ‘G’ gets greater until at the symmetrical G limit it should not be rolled at all.

Manoeuvre Envelope

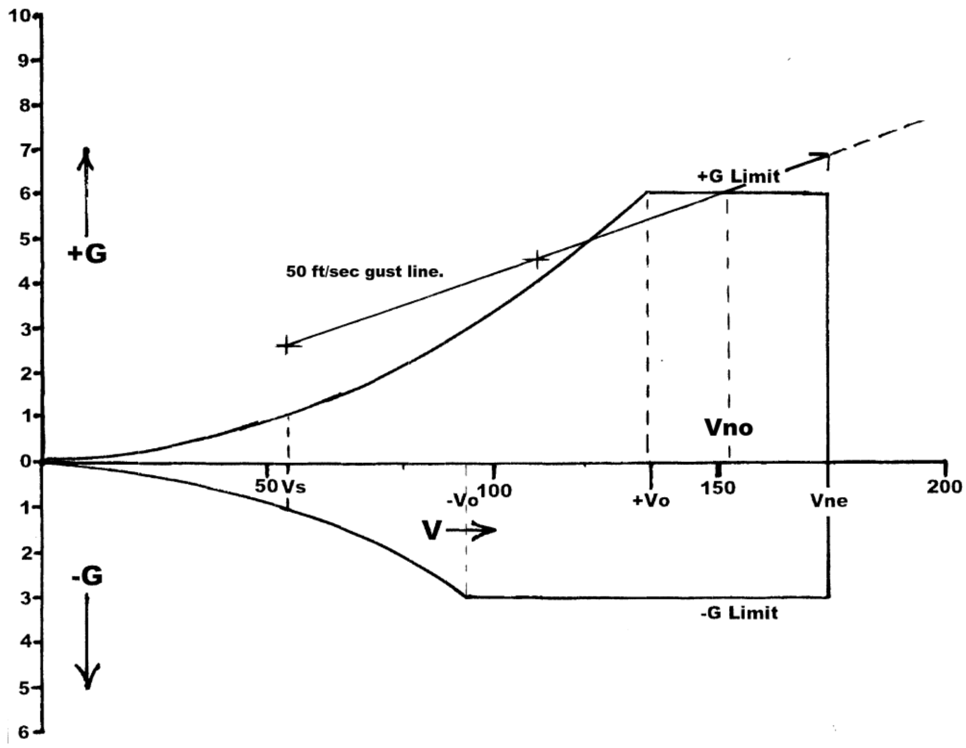
So we now have a graph which defines all of the structural limits of the aeroplane. The curved lines represent the ‘stall boundary’ and the ‘G’ beyond this line is ‘unattainable’ because the wings will stall at the boundary, whilst the horizontal lines represent the acceleration limits imposed by the designer (or regulator), on any pitching manoeuvre the aviator might attempt when flying at speeds above **±Vo**, and the vertical line represents the speed limit beyond which the aeroplane should not be flown. These lines enclose an area which is called the aeroplanes ‘Manoeuvre Envelope’. Flight within this envelope is okay but flight outside it is either impossible or damaging to the aeroplane. All aeroplanes, regardless of the purpose for which they are designed, have Manoeuvre Envelopes similar to this, but the +/- acceleration limits and **Vs, Vo** and **Vne** will of course vary with each type.



(Sailplane pilots should also remember that their aircraft has a further G restriction whenever the 'airbrakes' are used.)

Vno

Unfortunately most pilots do not fully understand the meaning of **Vno**. They do not understand that it is a 'response speed' to a particular size gust, not a manoeuvring speed, so some may indulge in maneuvers the aeroplane was never designed to do at this speed, thinking "I am in the green arc, so it is OK"!!



Airspeed indicator markings

The standard markings on an Airspeed Indicator are: a green band from **Vs** to **Vno**, a yellow ('caution') band from **Vno** to **Vne** and a red radial line at **Vne**. Unfortunately **Vo** and **Vb** are <u>not</u> marked on an ASI!

Lesson Fourteen – Turning at the Limit

There is a direct relationship between the speed and the rate of turn at a given radius, and the rate of turn and the radius of turn at a given speed. An aeroplane 'cornering' twice as fast is not only going around the current corner twice as fast (double the turn rate), but can also convert more of the extra lift into Cp by virtue of the increased bank angle which is possible, and therefore reduce the

turn radius significantly. So, to fly a minimum radius and maximum rate level turn, we must have the lowest wing loading possible, the lowest density altitude possible, the fastest airspeed possible (up to Vo), the maximum **C**L possible, and the appropriate bank angle to maintain level flight.
I am aware that many pilots and flying instructors advocate that when flying in mountain valleys the aircraft should be slowed and flap extended in the belief that it will enable them to turn 'tighter', but in most cases this just isn't so. If the aeroplane is capable of flying at the 'corner' of the manoeuvre envelope then this is where it should be flown. 'The corner' is where the stall boundary line of the aircraft's manoeuvre envelope 'turns the corner' at the 'G' limit line. In other words, at **Vo** and Max G on the stall 'buzz'. That is where you get 'min radius/max rate' turns.

In order to make a level 'U turn' in a valley most efficiently in a normal GA aeroplane, the pilot should initiate a turn at the structural limit of the aeroplane, apply full power, and whilst holding the angle of attack at the critical angle (on the buzz) progressively reduce bank as the aeroplane slows such that the vertical component of lift is always **1**, that is, to maintain level flight.

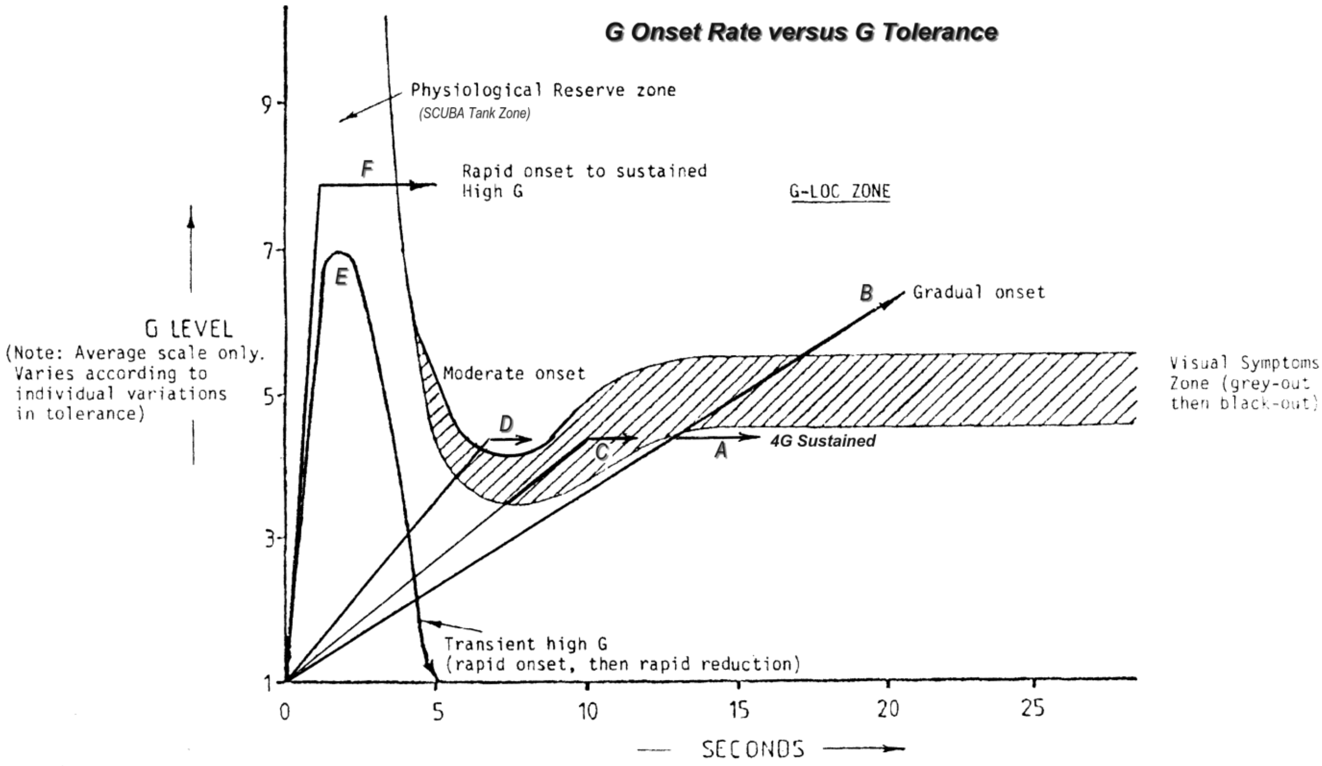
Lesson Fifteen – Human Limits

If the heart can take up to 15 seconds to respond to increased demand but the brains oxygen reserve can be consumed in only 5 seconds, what does the brain do for the other 10 seconds? ......Why, it goes to sleep!!

The modern acronym for this 'going to sleep' is 'GLOC', which stands for **G** induced **L**oss **O**f **C**onsciousness. Back in the 'good old days' this was called 'Black Out', because you obviously lose vision when you 'go to sleep'. But it is possible to 'Black out' without GLOC! How can this be? Well; the different cells of the eyes use the oxygen in their 'Scuba Tanks' at different rates, so it is possible to progressively loose vision prior to GLOC as the G builds. First colour acuity goes, then peripheral vision and finally focal vision fails over about a 1G range. So what we see initially goes grey, followed by 'tunnel vision' and finally black! This progressive loss of vision is often regarded as the 'early warning' of impending GLOC but occasionally the rate of increase of G and the level of G sustained, can be such that only black out occurs and the increasing heart rate 'saves the day' for the brain. It is a fine line to draw.

A common mis-belief is that once the G is relaxed, consciousness returns immediately. It doesn't! Vision is the first thing to return once the G is relaxed but it takes 'Joe Average' 20-30 seconds to regain useful consciousness once he has GLOC'd. By "useful" I mean being able to respond to the situation around him. His eyes will be open and he may be able to utter phrases like "what happened?" or "where am I?" etc, after 10-15 seconds, but this is hardly useful.

The 'G' tolerance graph



Lesson Sixteen – Spinning

Watch him spin, watch him burn.
He held off bank in a gliding turn!

Yaw at the point of stall causes autorotation and spinning. No yaw, no spin, so keep the 'ball' in the middle (unless in a controlled side slip).

The spin recovery procedure

1. **Throttle off**
2. **Confirm spin direction**
3. **Hands off**
4. **Full opposite rudder**
5. **When the rotation stops get off the rudder**
6. **Grasp the stick and pull out of the dive**

It's that simple!

Annex A

Table of 'Vs' Speeds

In this book and in book one, various key speeds have been referred to as multiples of Vs. The following is a quick reference table of those speeds.

Vs	Speed at critical angle of attack in straight and level (un-accelerated) flight, at maximum all up weight, with flaps up and undercarriage retracted.
1.1Vs	Speed at critical angle of attack in a 30º banked turn.
1.2Vs	Speed at critical angle of attack in a 45º banked turn. Minimum Power Speed. Best Endurance Speed. Best Angle of Climb Speed. (Approx.) Minimum Sink Speed when Gliding. Threshold Speed for Short Landing.
1.3Vs	Threshold Speed for Normal Approach and Landing. Reference Velocity (Vref) for safe low speed manoeuvring.
1.4Vs	Speed at critical angle of attack in a 60º banked turn. Speed for Best L/D Ratio. Minimum Drag Speed. Best Range Speed. Best Rate of Climb Speed. (Approx.) Best Glide Angle Speed.

Note: These reference speeds still apply, where applicable, when Vs becomes Vsm during manoeuvring. For example:

> In a 45º banked turn Vs increases by 20% to 1.2Vs, so the minimum sink speed when turning at this angle of bank whilst gliding becomes 1.2 x 1.2 Vs = 1.4 Vs